



# $\beta$ DF and $\alpha$ -decay spectroscopy of $^{194,196}\text{At}$

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\* This work was performed by RILIS-ISOLDE (CERN) – University of York (UK) – IKS, KU Leuven (Belgium) – SCK-CEN, Mol (Belgium) – Comenius University, Bratislava (Slovakia) – OLL, University of Liverpool (UK) – JAEA, Tokai (Japan) – Gatchina (Russia) collaboration.

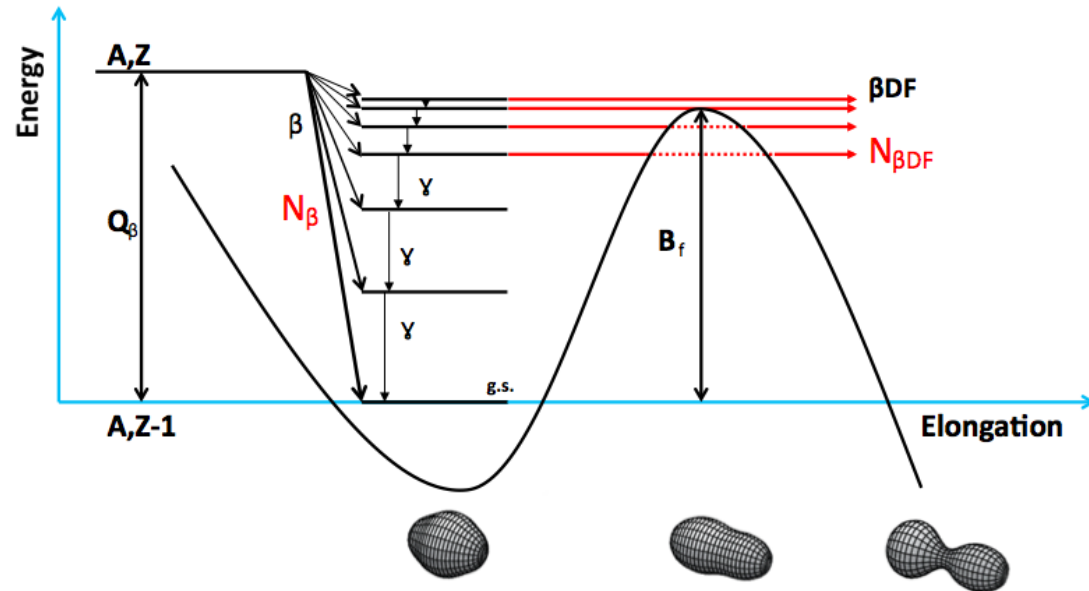


# Overview

- $\beta$ -delayed fission ( $\beta$ DF)
  - Introduction & motivation
- Experiment
  - ISOLDE
  - Windmill
- Data
- Analysis
  - $\alpha$ -decay spectroscopy
  - $\beta$ DF
- Conclusion and Outlook

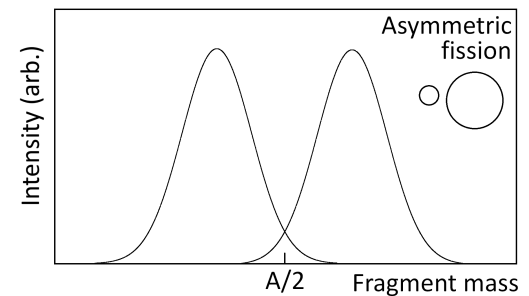
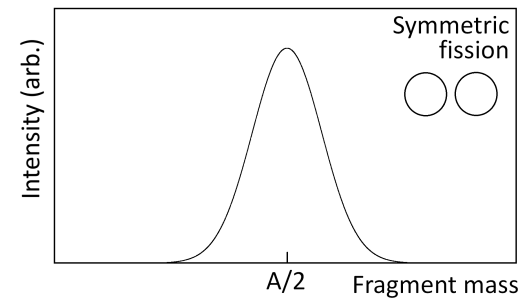
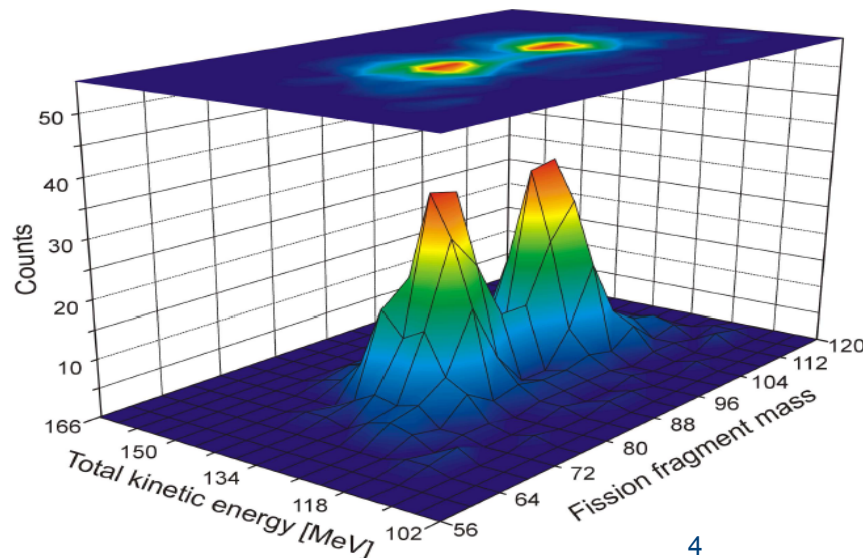
# $\beta$ -delayed fission ( $\beta$ DF)

- 2-step process
  1.  $\beta$  decay of parent
  2. Fission of daughter
- Fission if excitation  $E (< Q_\beta) \sim B_F$
- Low energy fission (influence of microscopic effects)
- Spin/Parity dependence
- Study partial half-life as function of  $Q_\beta$  and  $B_F$



# $\beta$ DF in the neutron-deficient Pb region

- Unexpected asymmetric fission of  $^{180}\text{Hg}$ 
  - Expected:  $^{180}\text{Tl} \rightarrow ^{180*}\text{Hg} \rightarrow ^{90}\text{Zr} + ^{90}\text{Zr} = \text{Symmetric}$
  - Observed:  $^{180}\text{Tl} \rightarrow ^{180*}\text{Hg} \rightarrow ^{100}\text{Ru} + ^{80}\text{Kr} = \text{Asymmetric}$





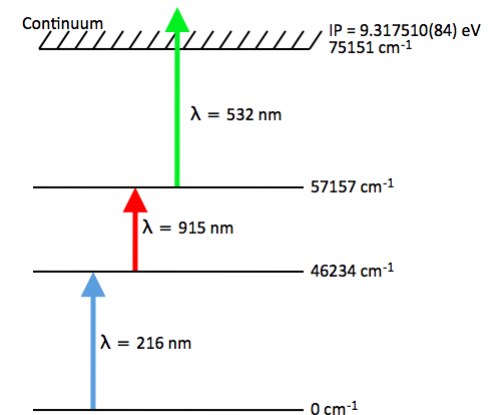
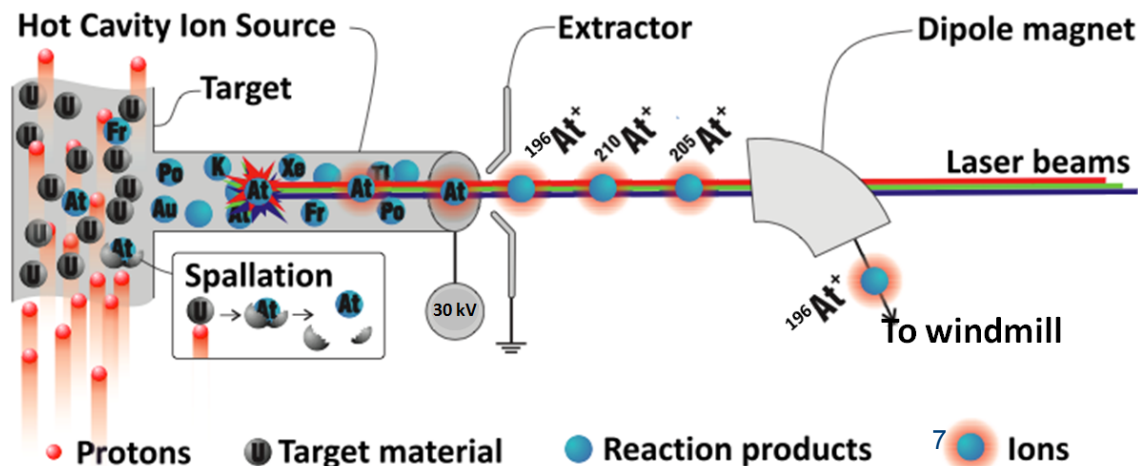
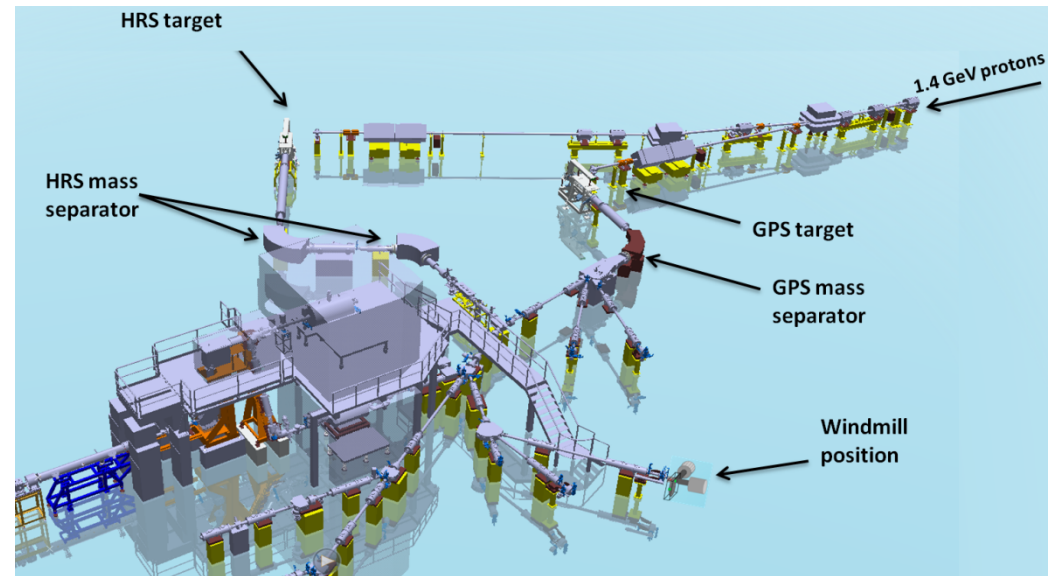
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# Experiment - ISOLDE

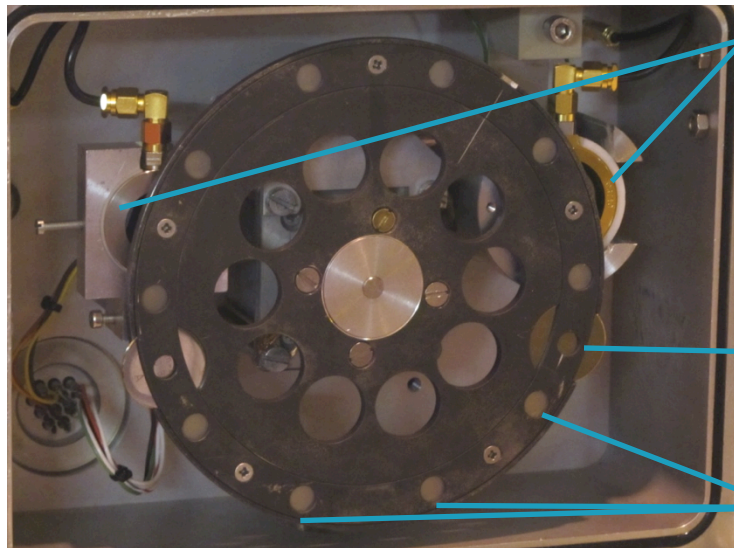
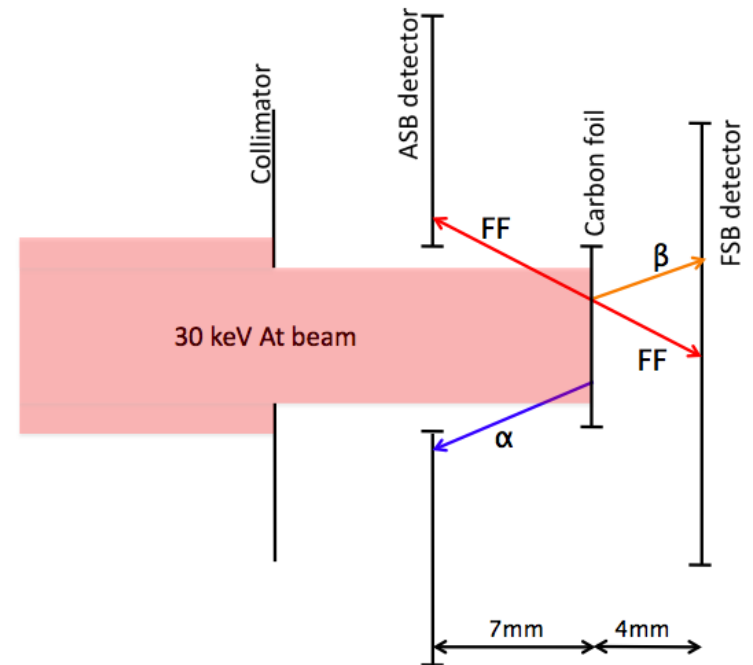
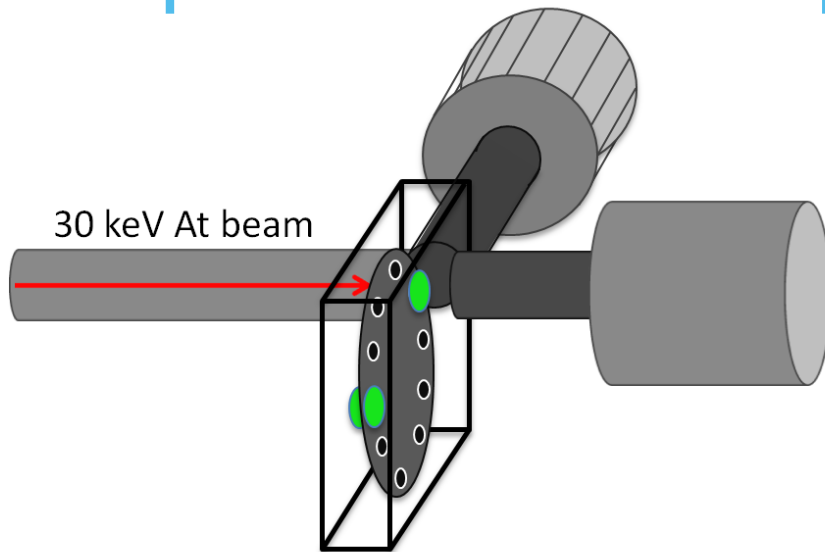
<http://Isolde.web.cern.ch/isolde> (2013)

- 2  $\mu\text{A}$  protons on  $\text{UC}_x$
- 3-step ionization (RILIS)
- 30-60 keV extraction
- Mass separation with HRS or GPS



**KU LEUVEN**

# Experiment - Setup



Si detectors

$^{241}\text{Am}$

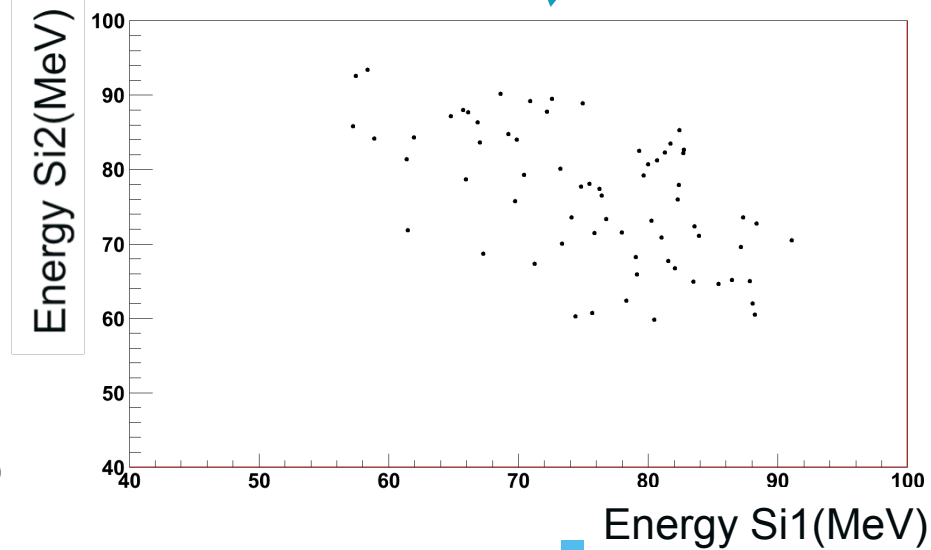
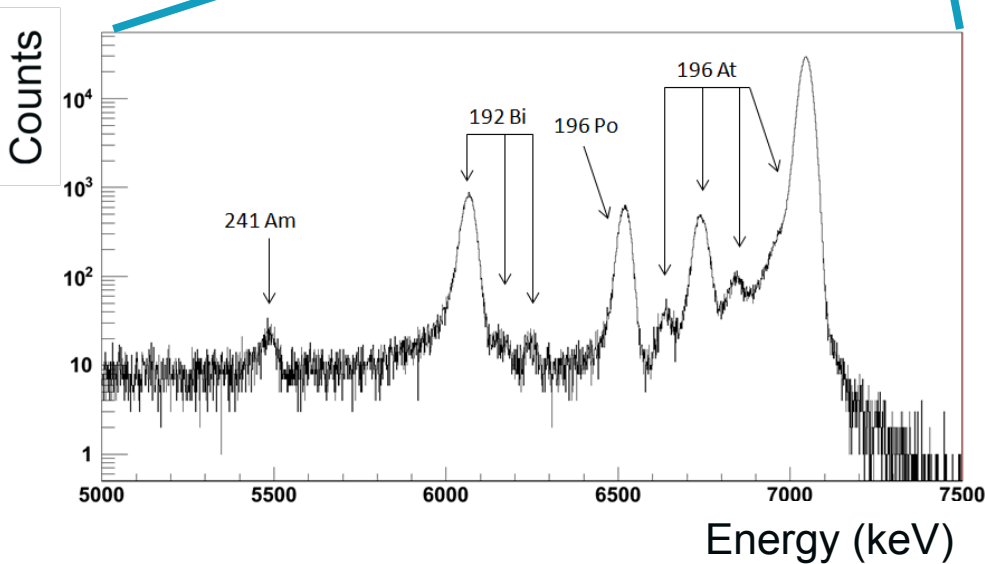
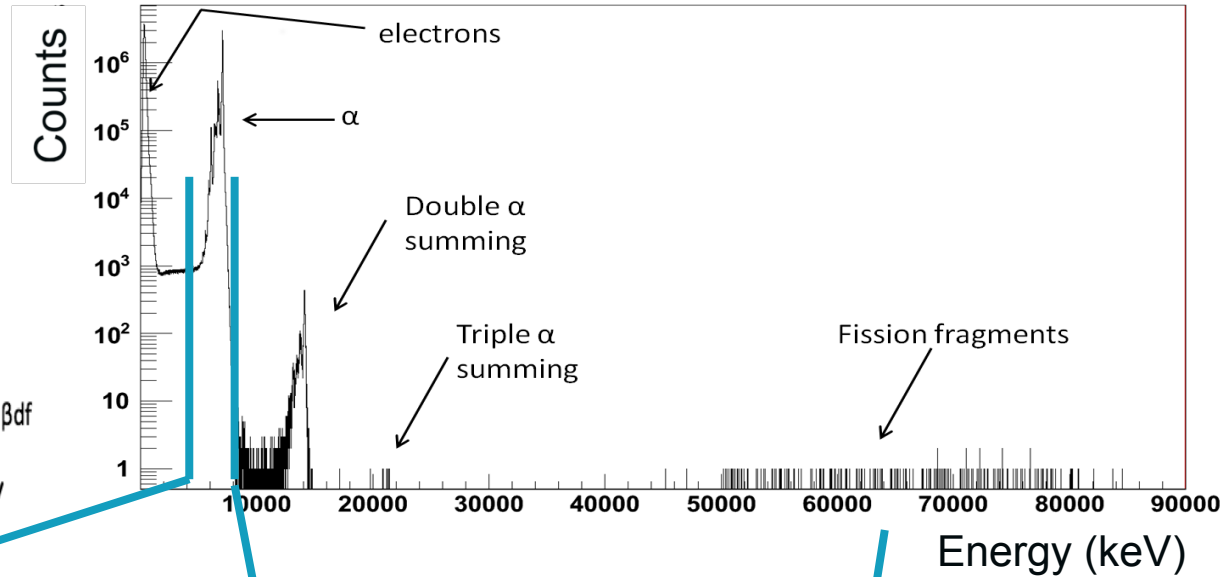
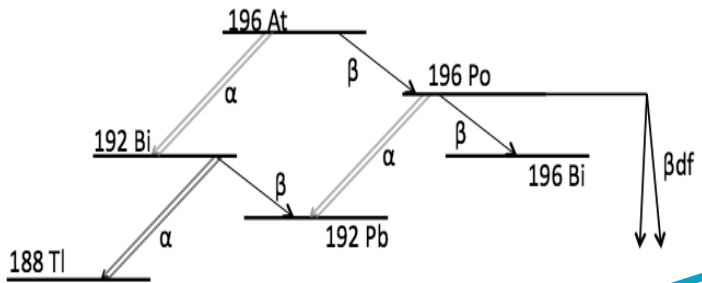
C-foils



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# Data



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# Analysis : $\beta$ DF of $^{194,196}\text{At}$

Measured pulse height to  
fragment mass conversion

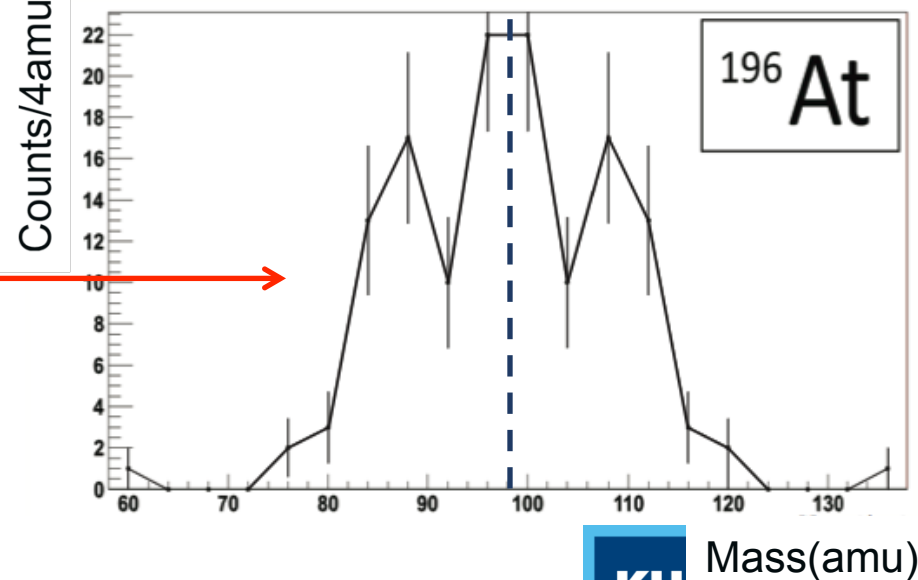
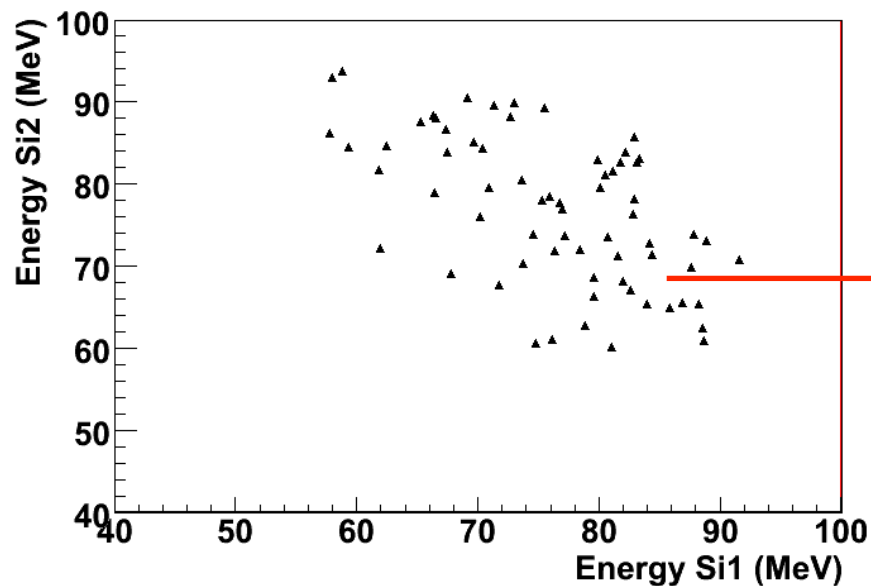
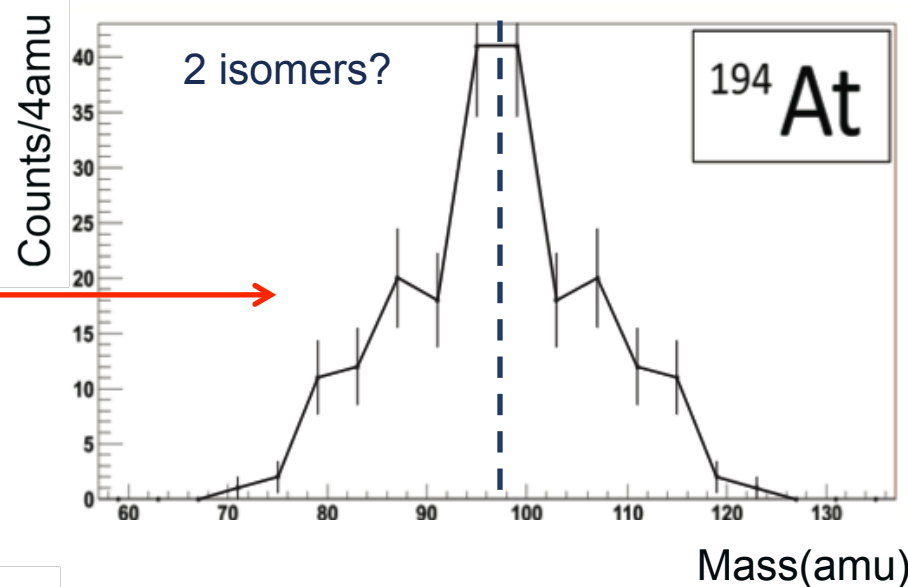
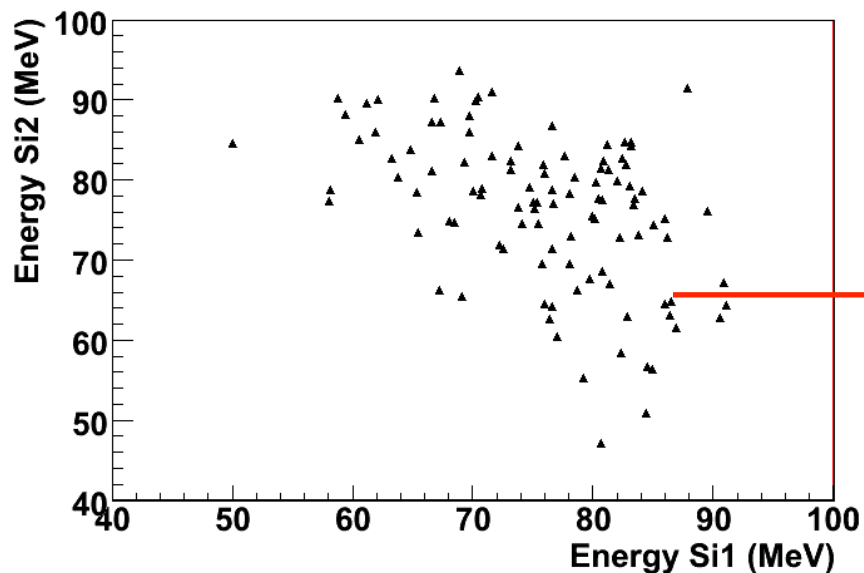
Schmitt calibration

Momentum conservation

Mass conservation

$$\left\{ \begin{array}{l} E_i^* = (a_i + a'_i m_i^*) x_i + b_i + b'_i m_i^* + \Delta E_{foil,i} \\ m_1^* E_1^* = m_2^* E_2^* \\ m_1^* + m_2^* = A_f \end{array} \right.$$

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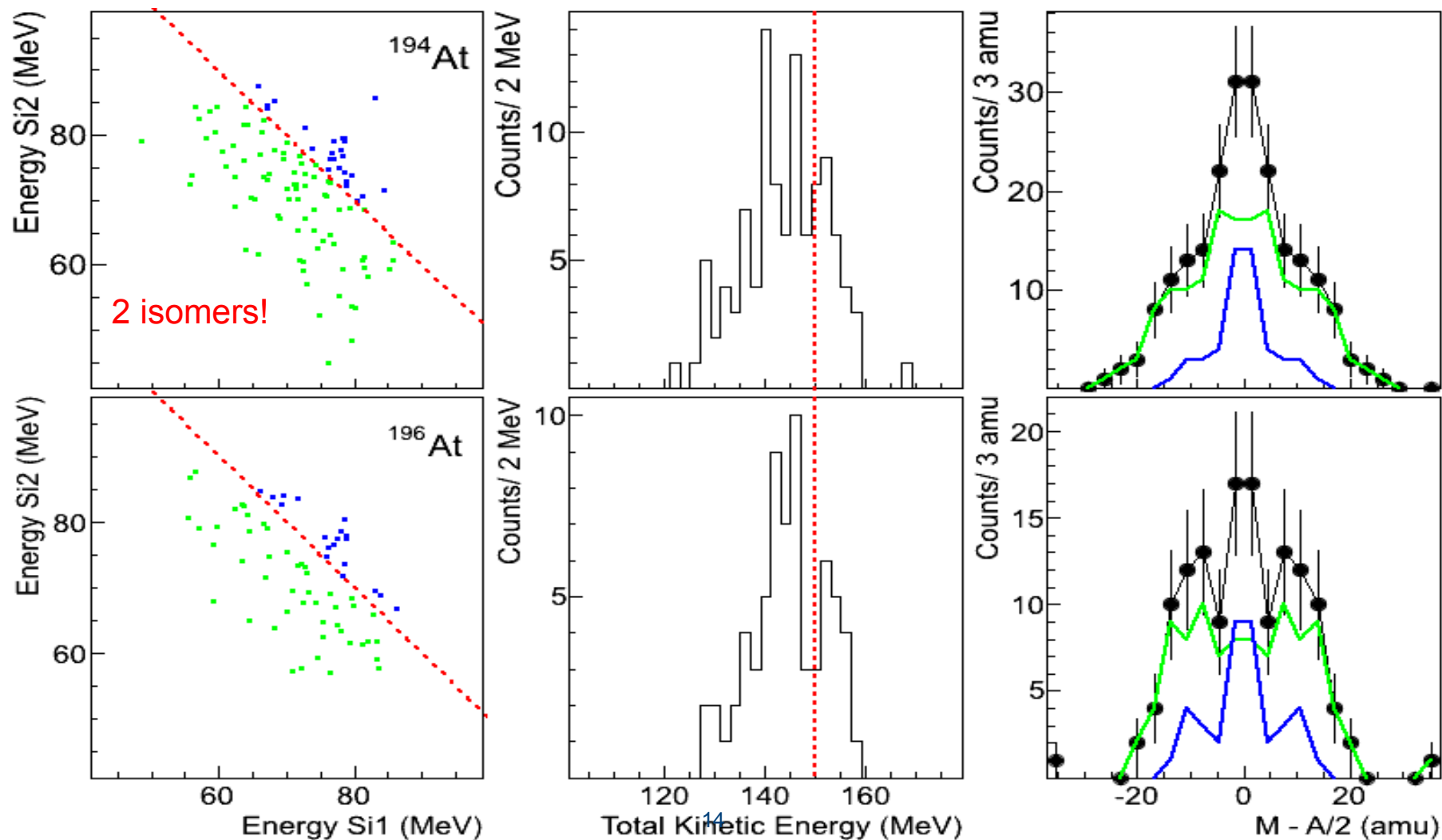
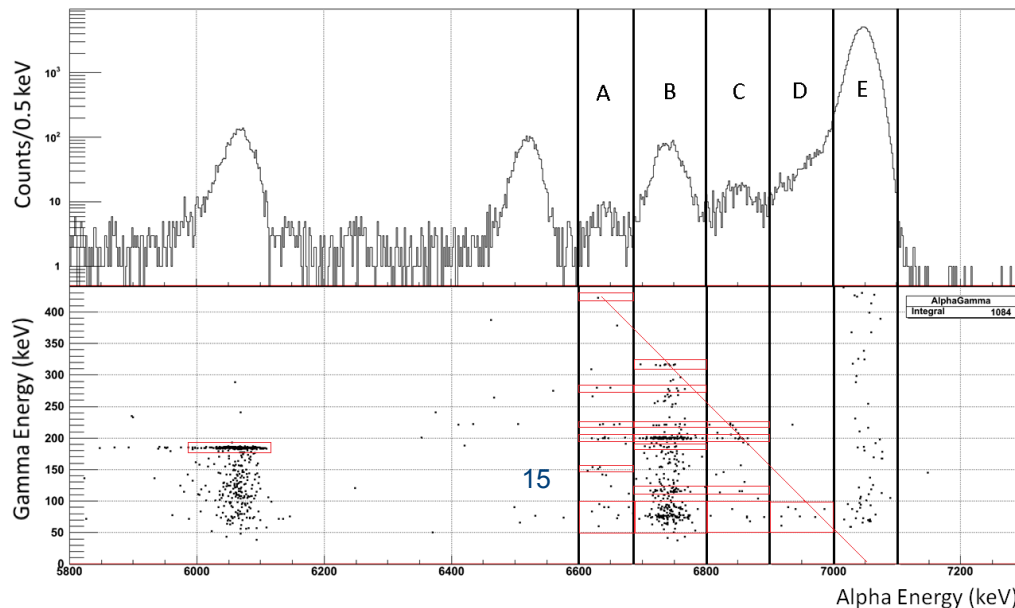
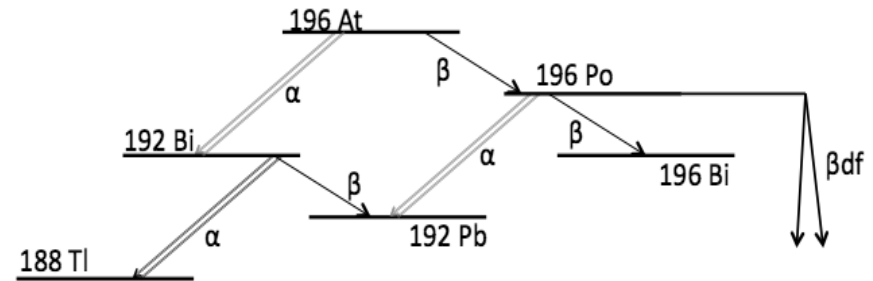


Figure: L. Ghys et al., "Multimodal fission in proton-rich nuclei", paper in preparation

# Analysis : $\alpha$ -decay spectroscopy

- Prior to this work:
  - Only alpha decay of  $^{196}\text{At}$  to g.s. of  $^{192}\text{Bi}$  known
  - No levels in  $^{192}\text{Bi}$  known
  - Beta branch  $b_{\beta}(^{196}\text{At})$  from syst. in literature



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# Conclusion and Outlook

## Conclusion :

$\alpha$ -decay spectroscopy of  $^{196}\text{At}$  performed

- Unknown fine structure and gamma rays detected
- Preliminary Bi level scheme

Low energy fission studied using  $\beta\text{DF}$  of  $^{194,196}\text{At}$

- Two fission modes observed
- $P_{\beta\text{DF}}$  and partial half life calculated to be compared to other data

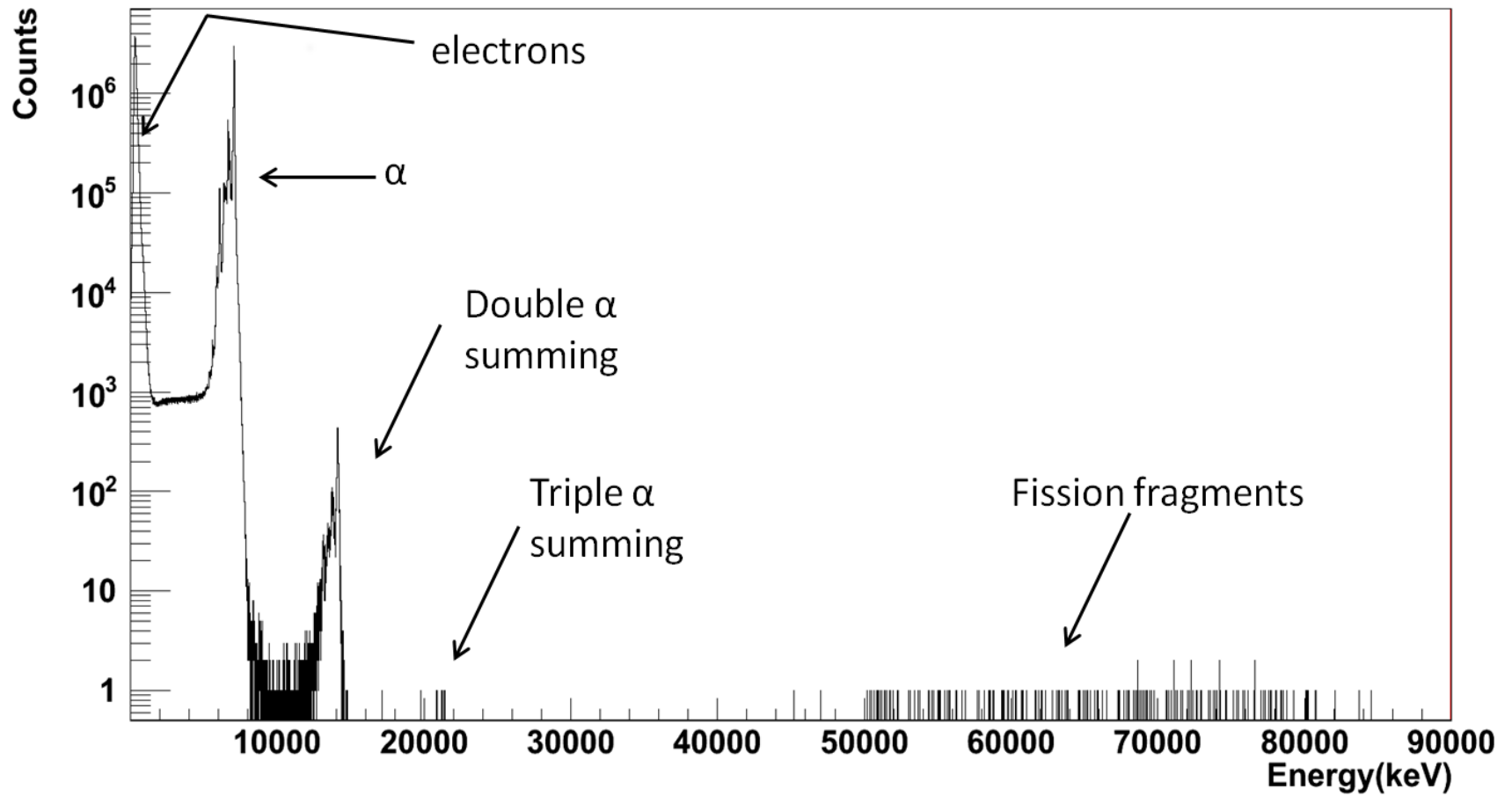
## Outlook :

- Compare observations to theoretical predictions
- Isomeric study of  $\beta\text{DF}$  for  $^{194}\text{At}$

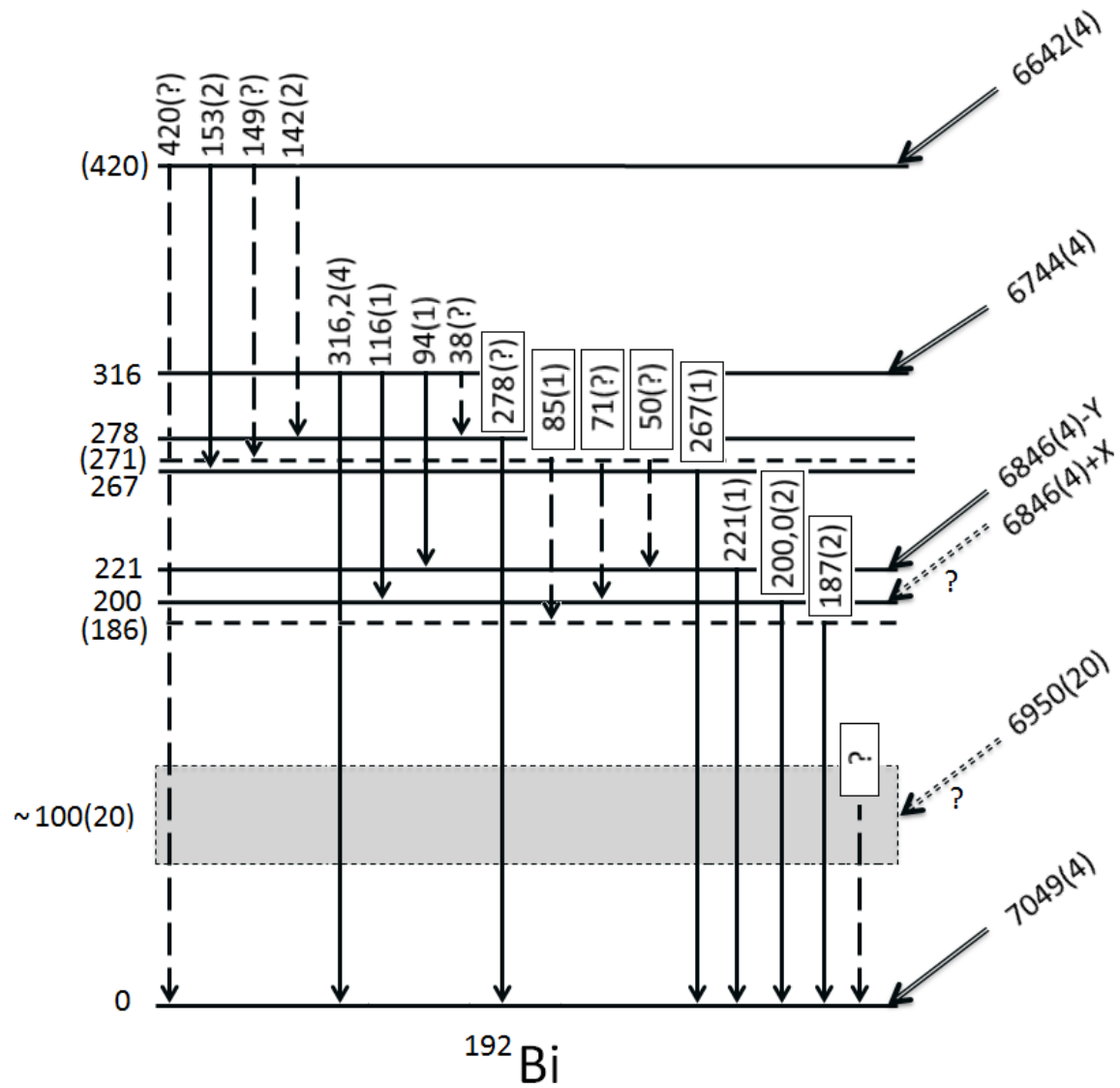
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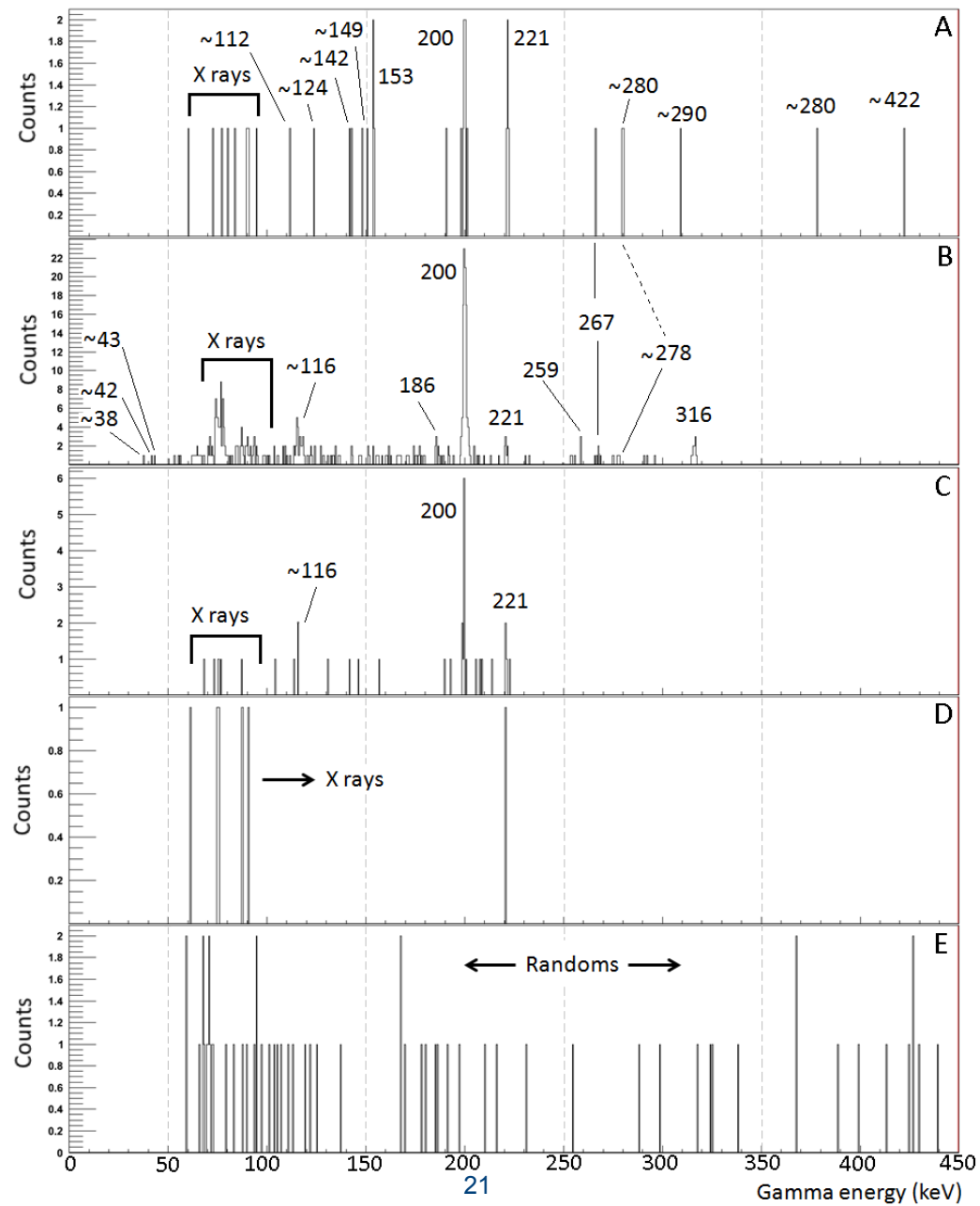


# Data

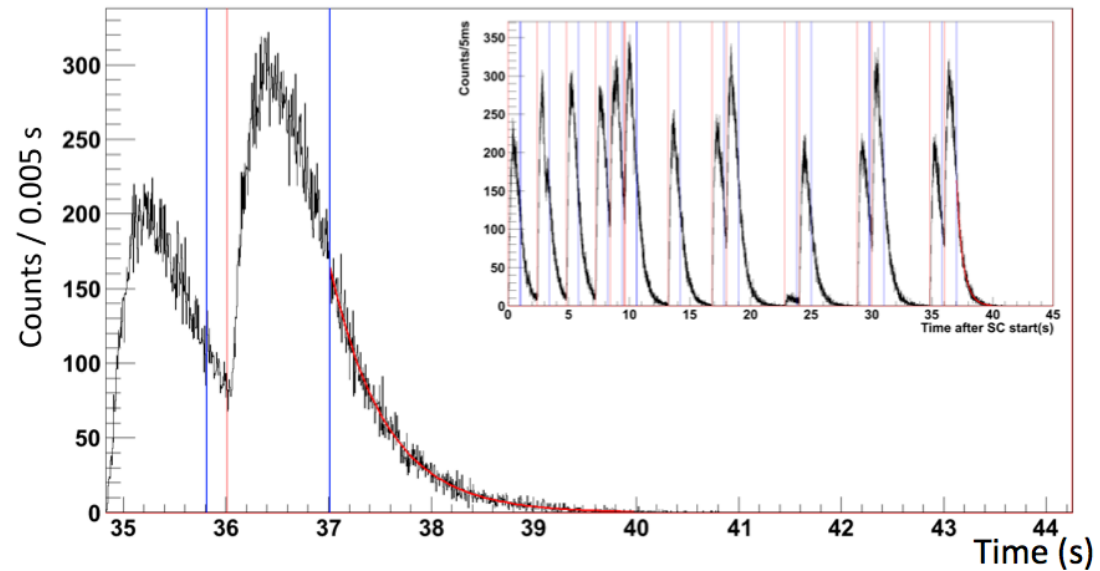
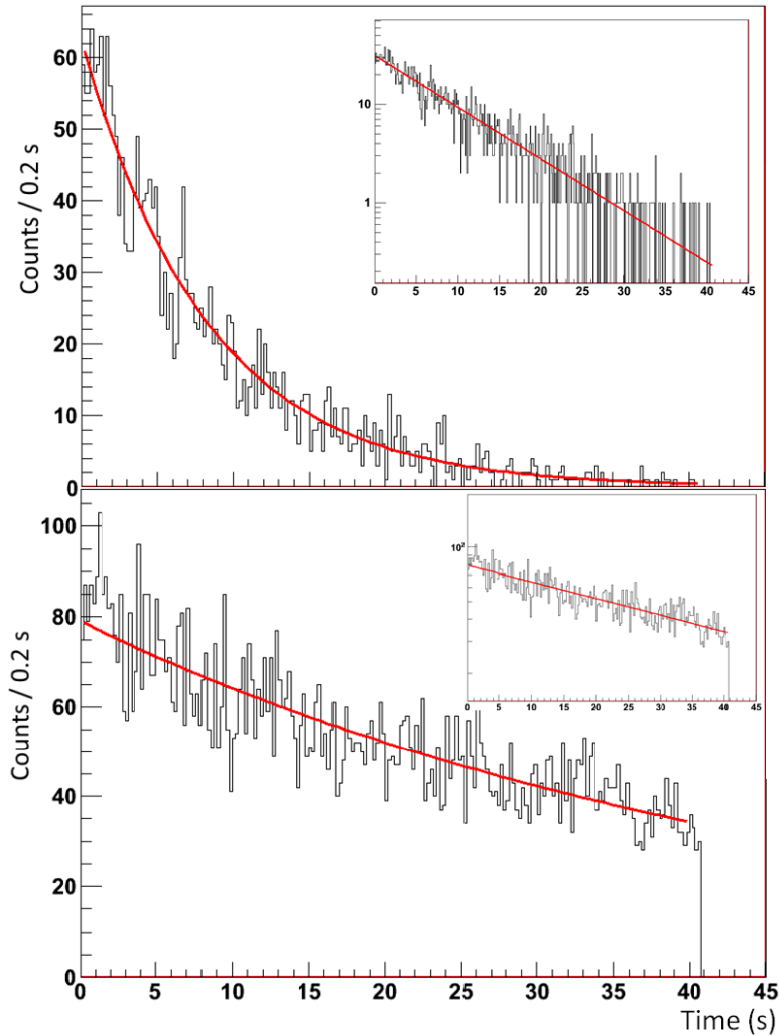


PRELIMINARY !!

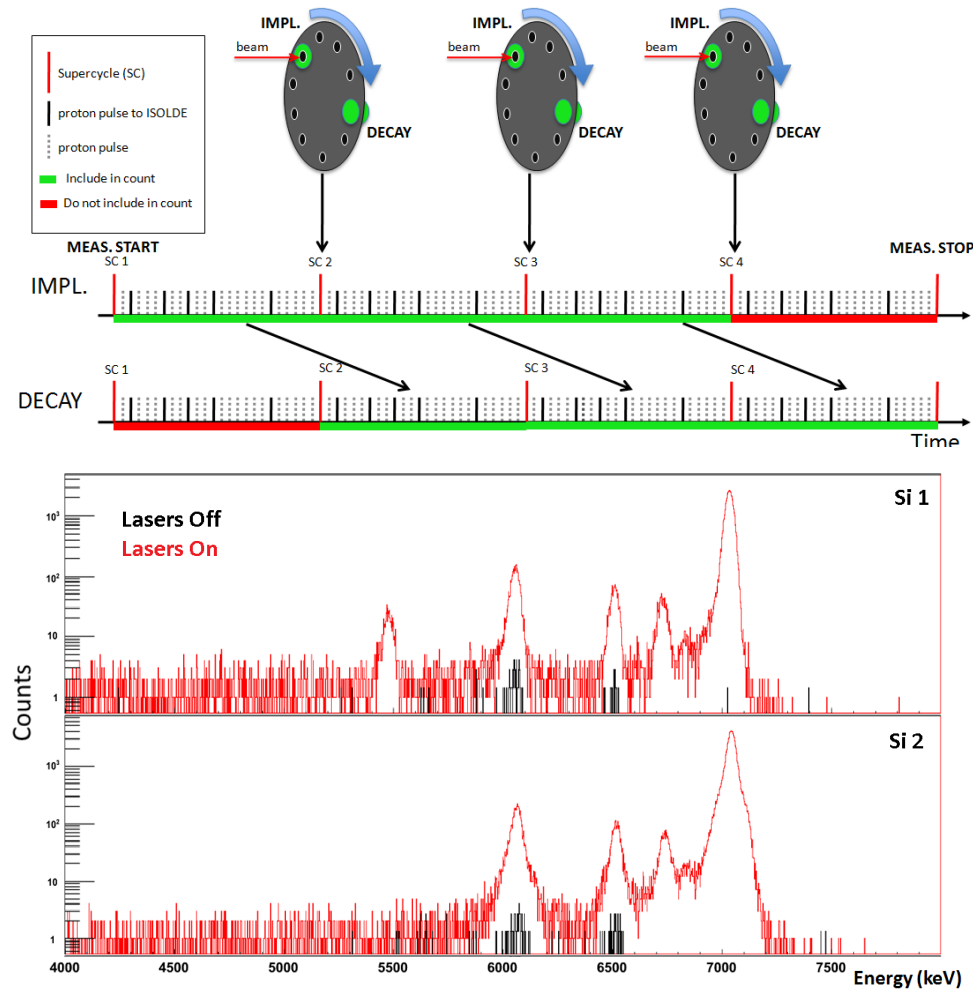
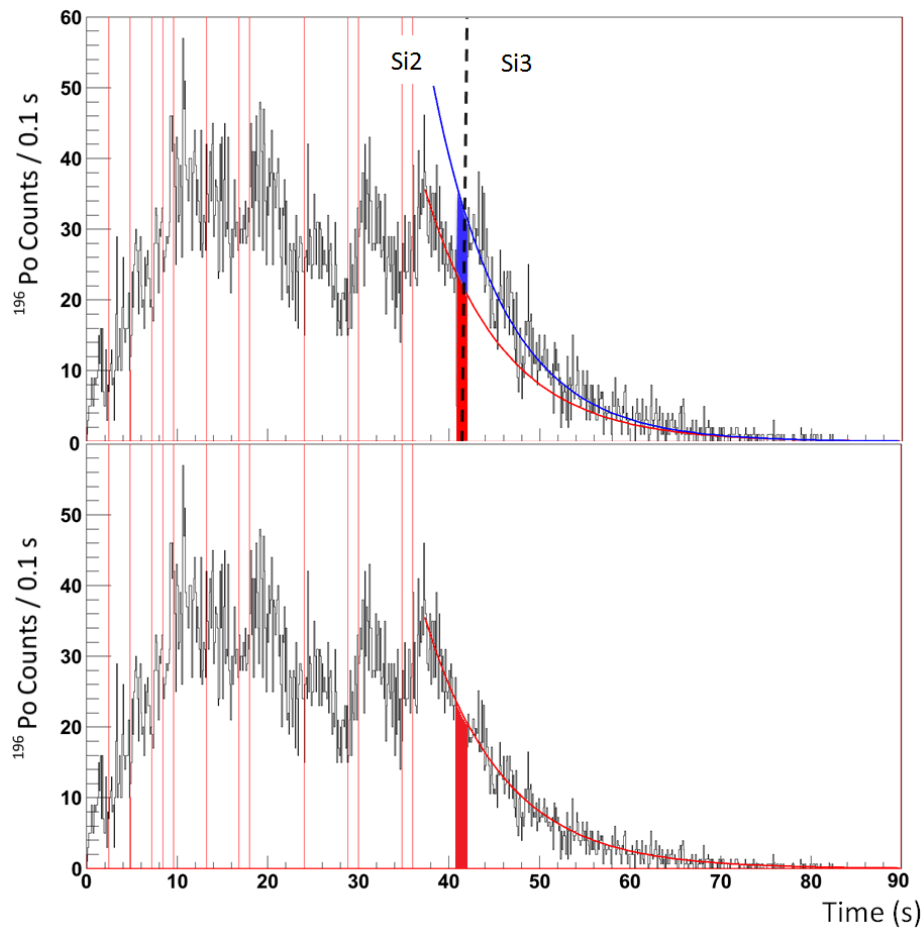




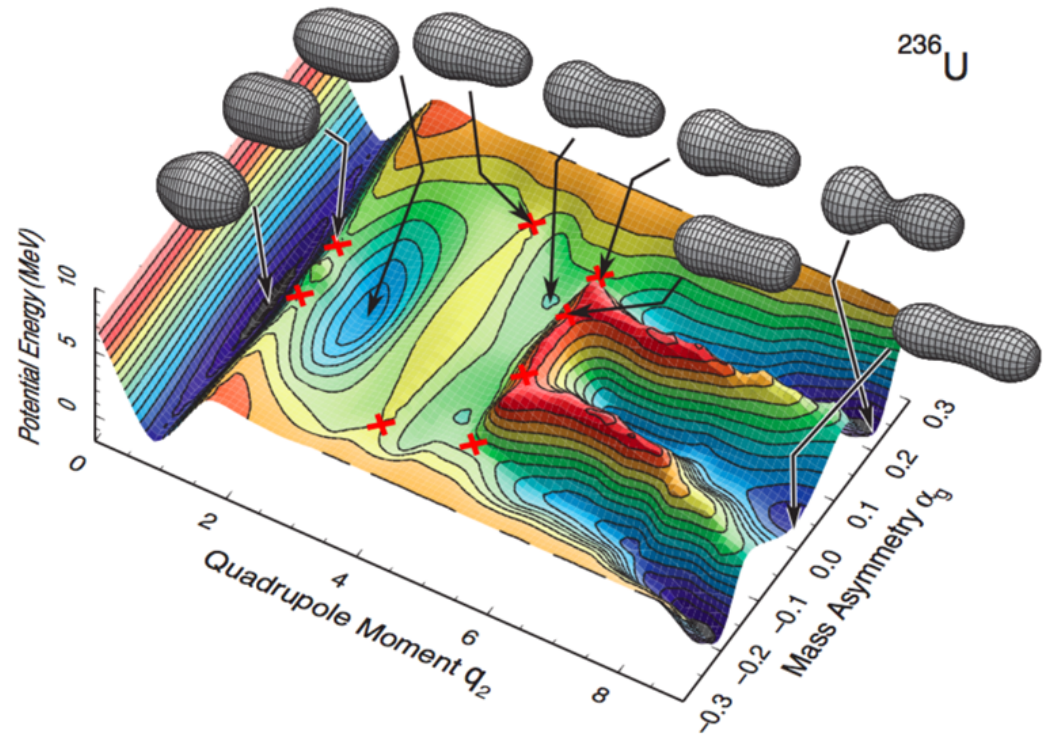
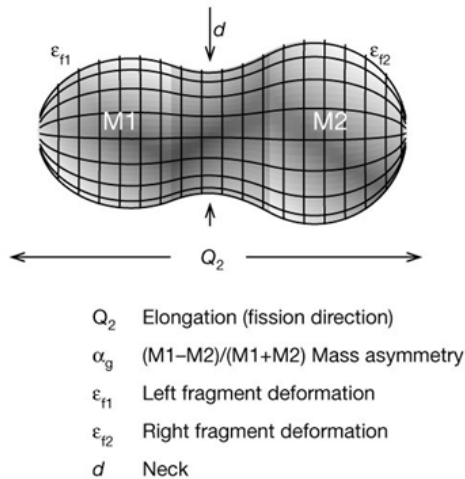
# Half-life measurements



# Beta branching calculation

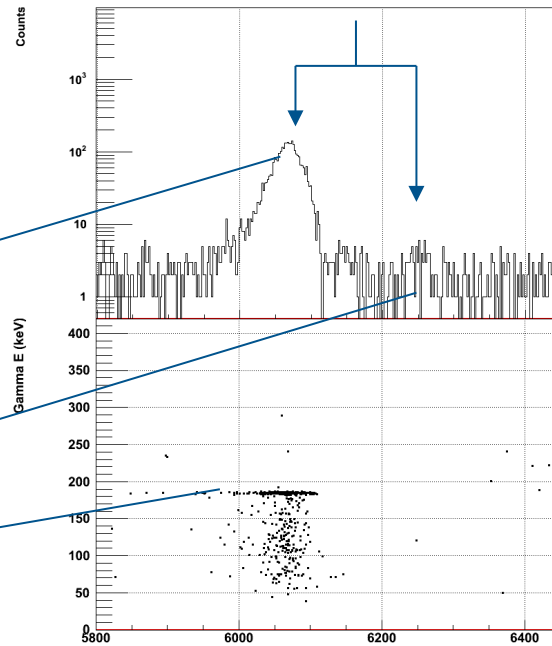
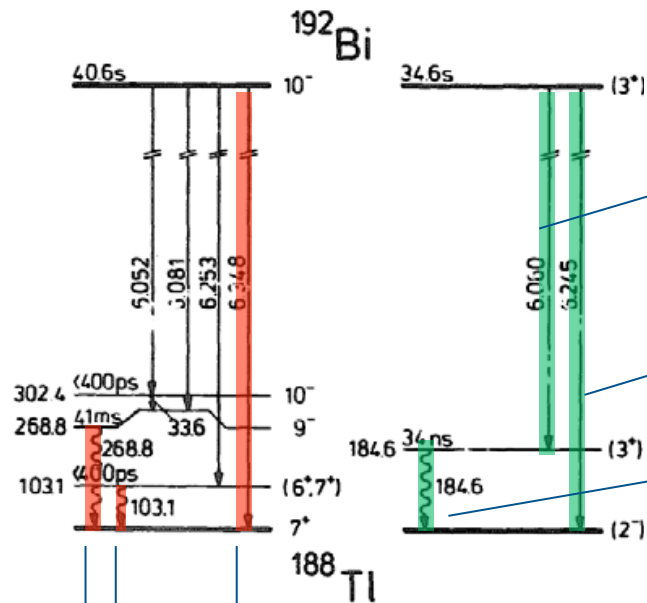


# How to maybe explain bimodal fission with PES

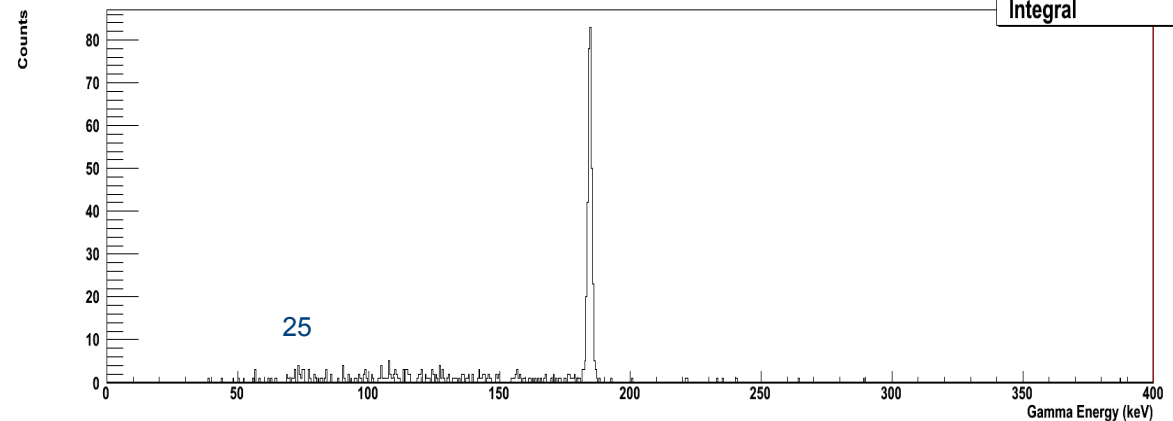




# Only populating I.s. $^{192}\text{Bi}$



Ratio: Exp = 0.032(5)  
vs Literat = 0.031(6)

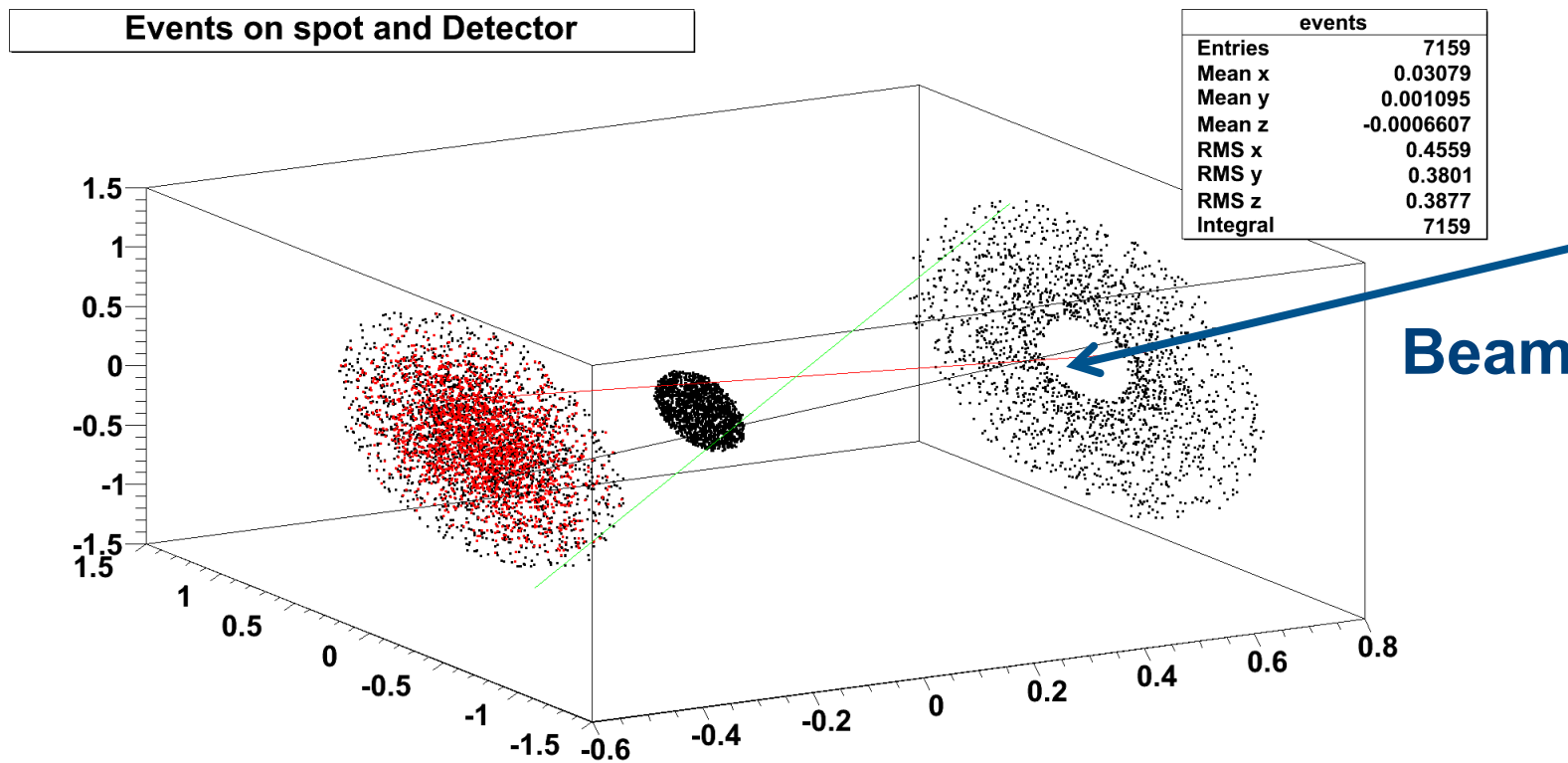


GammaProjection	
Integral	557

Should be able to distinguish clearly from other isomer, but don't see it.

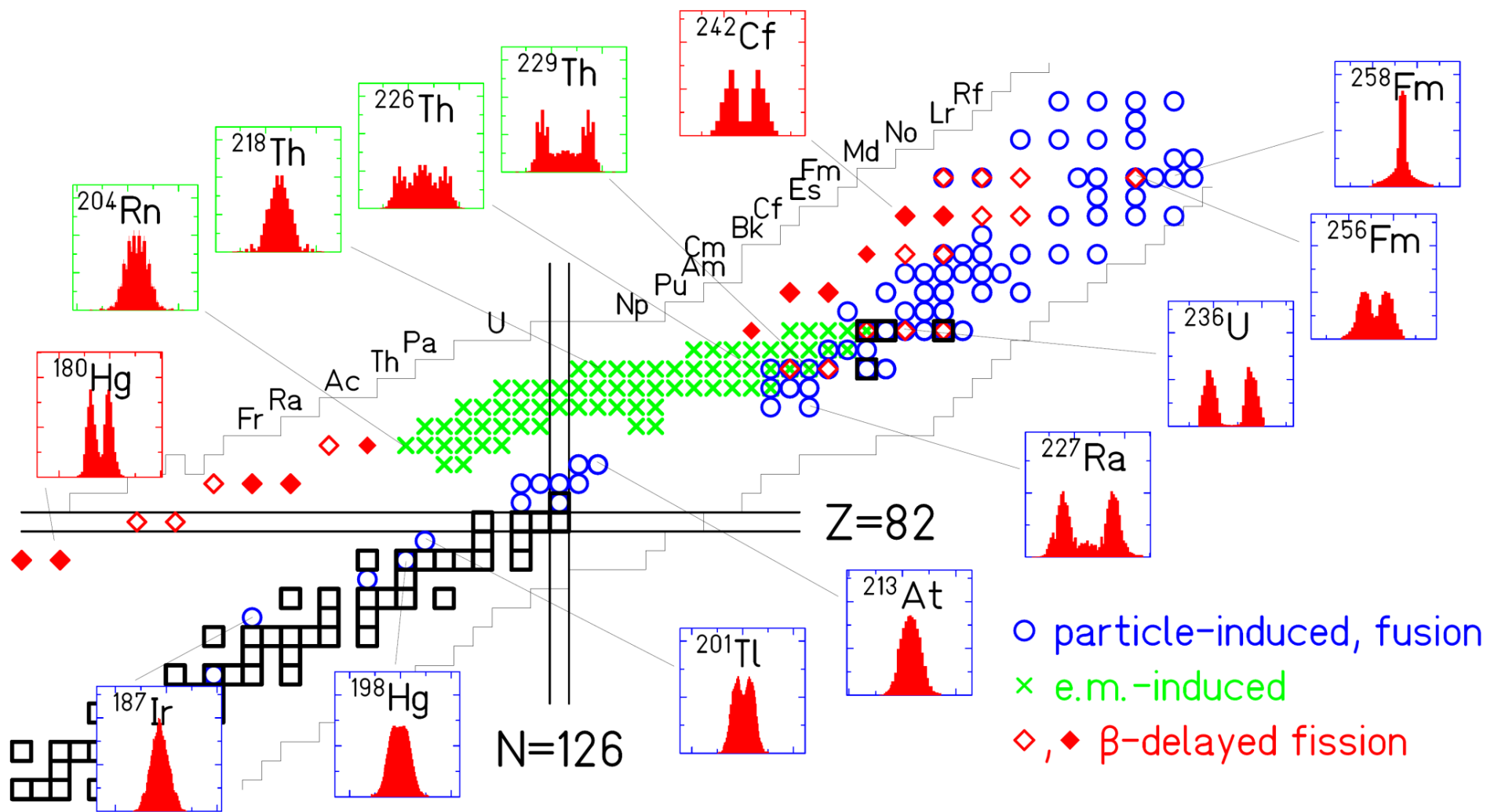
# Simulations

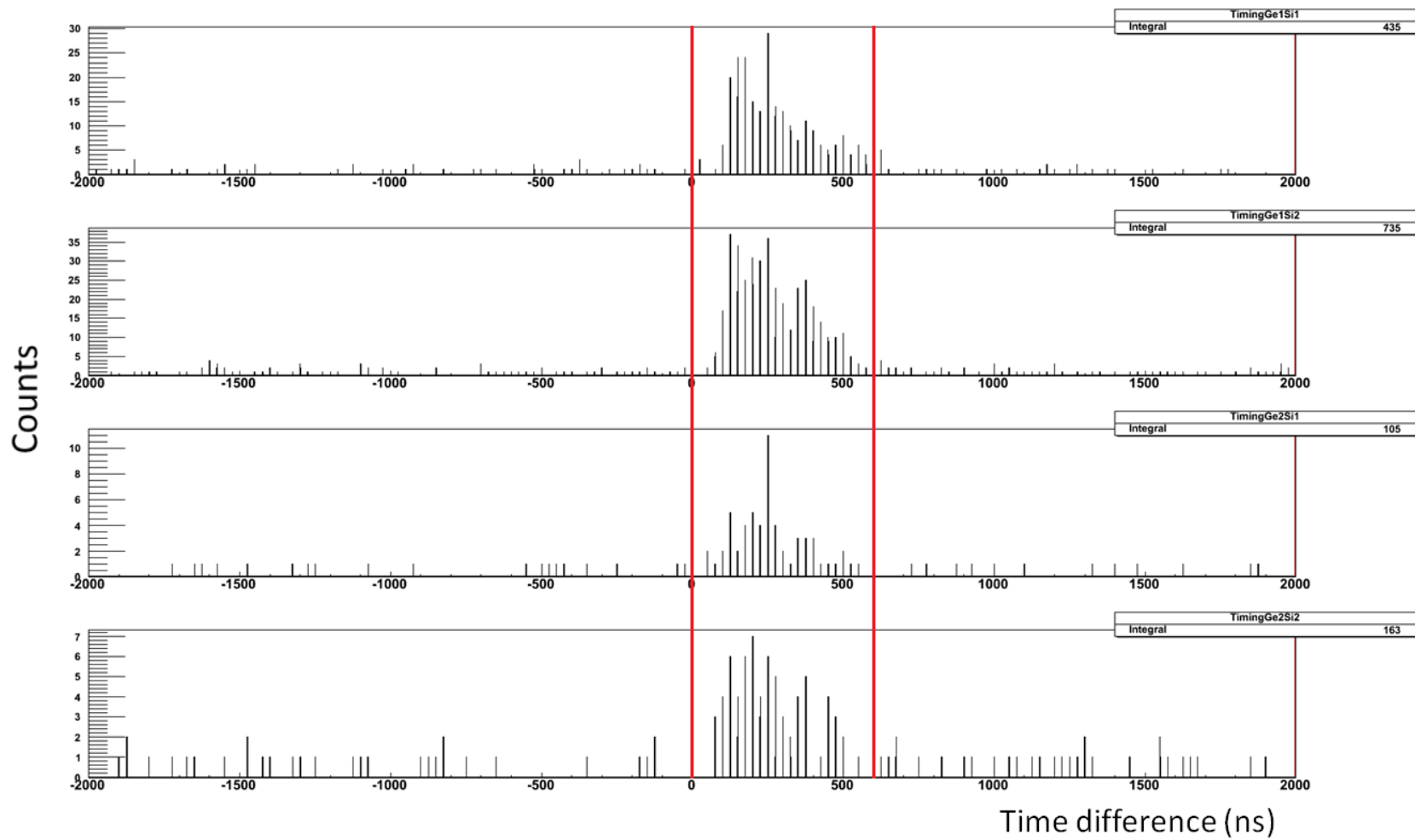
- Visualize simulation of events for our setup:

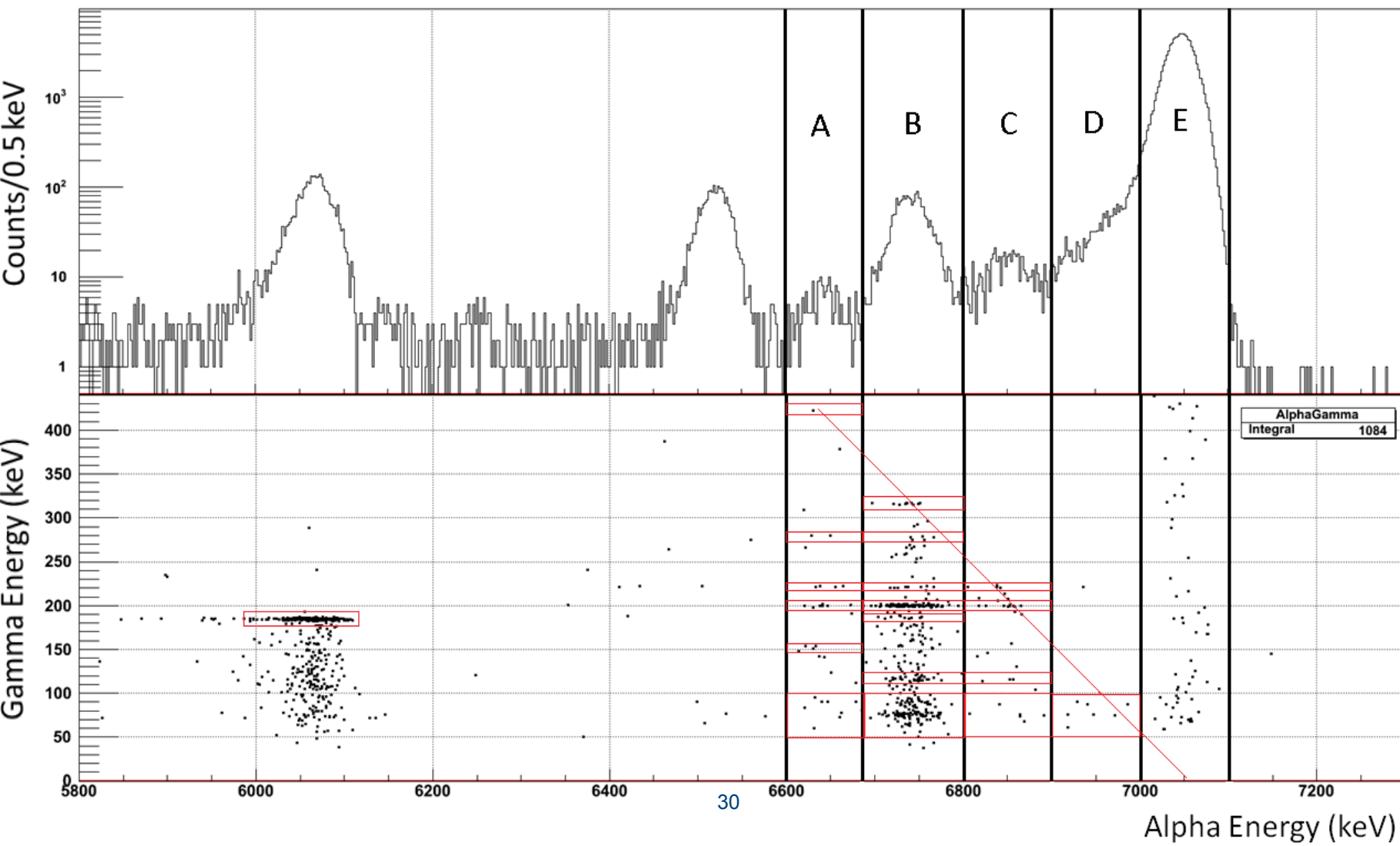


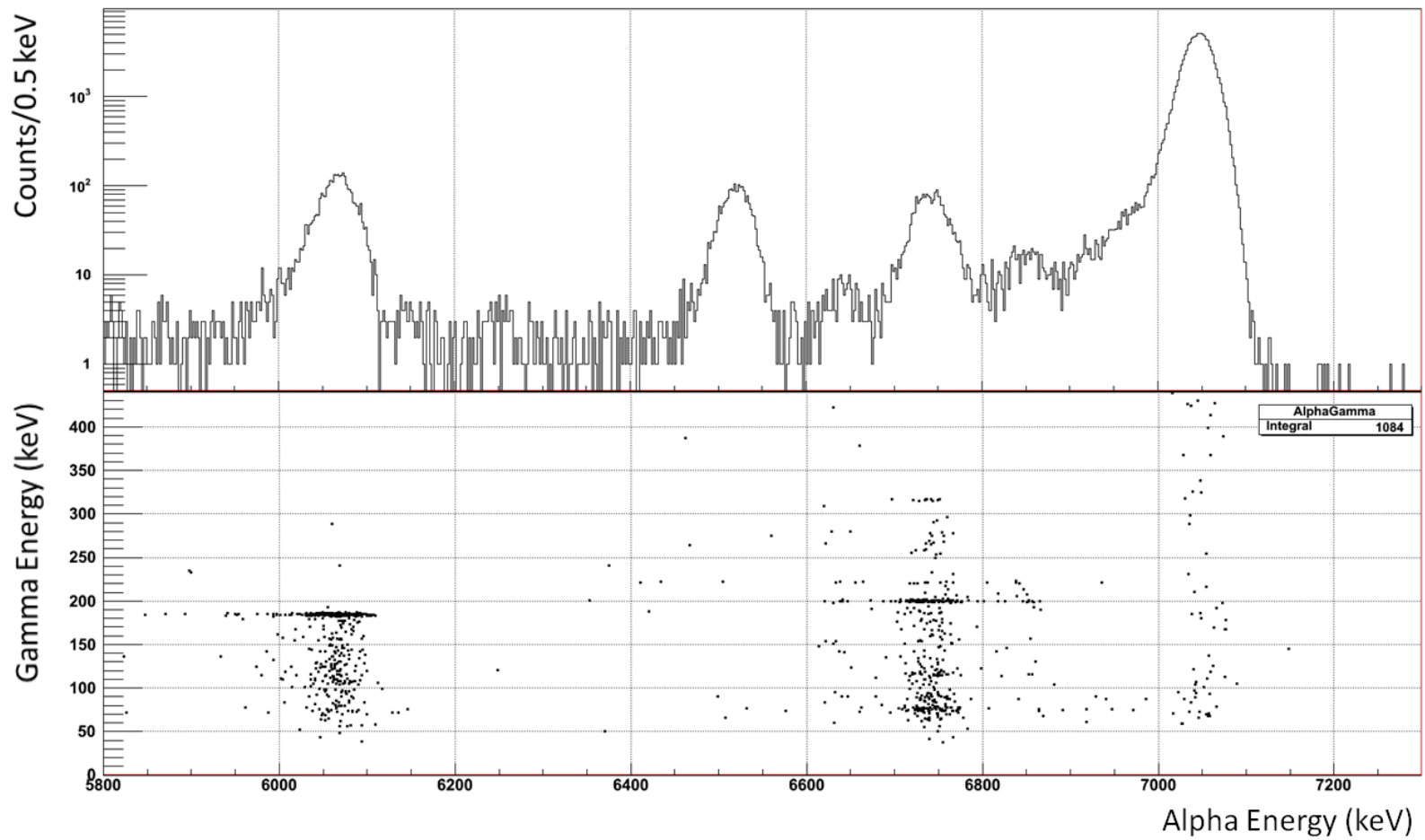
# Pulse height to energy and mass

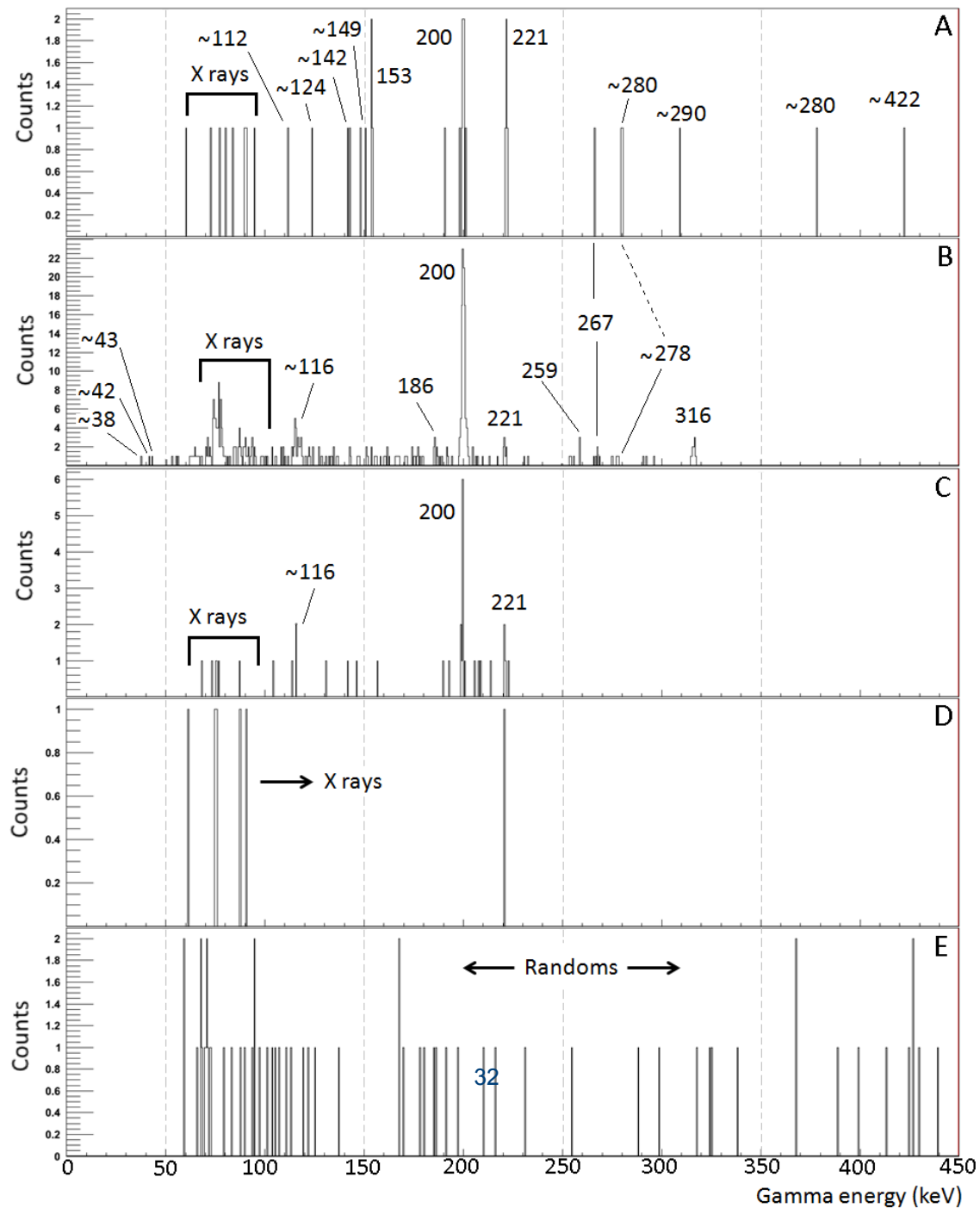
$$\begin{cases} E_i^* = (a_i/F_i + a'_i m_i^*)x_i + b_i/F_i + b'_i m_i^* \\ m_1^* E_1^* = m_2^* E_2^* \\ m_1^* + m_2^* = A_f \end{cases}$$



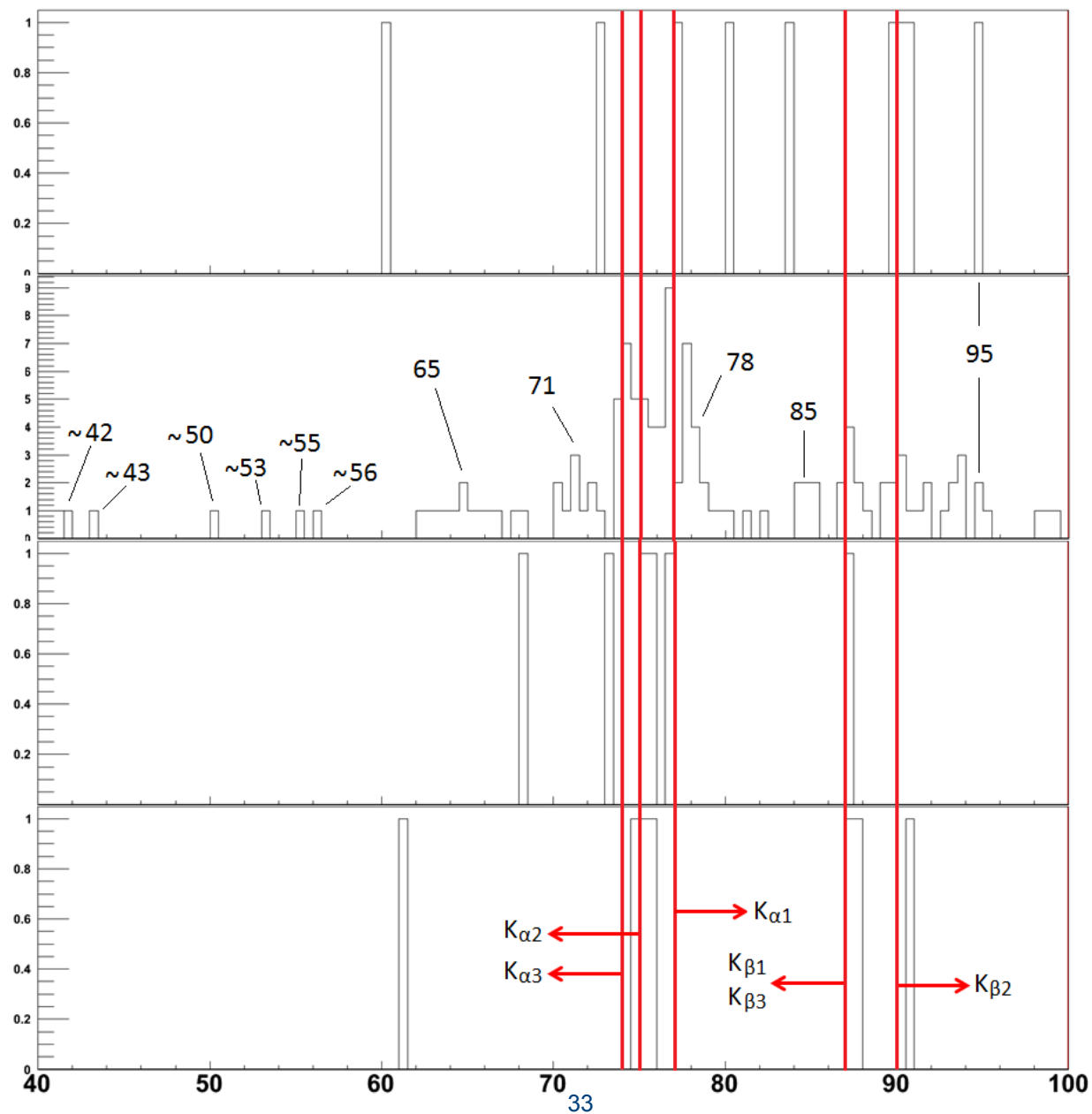


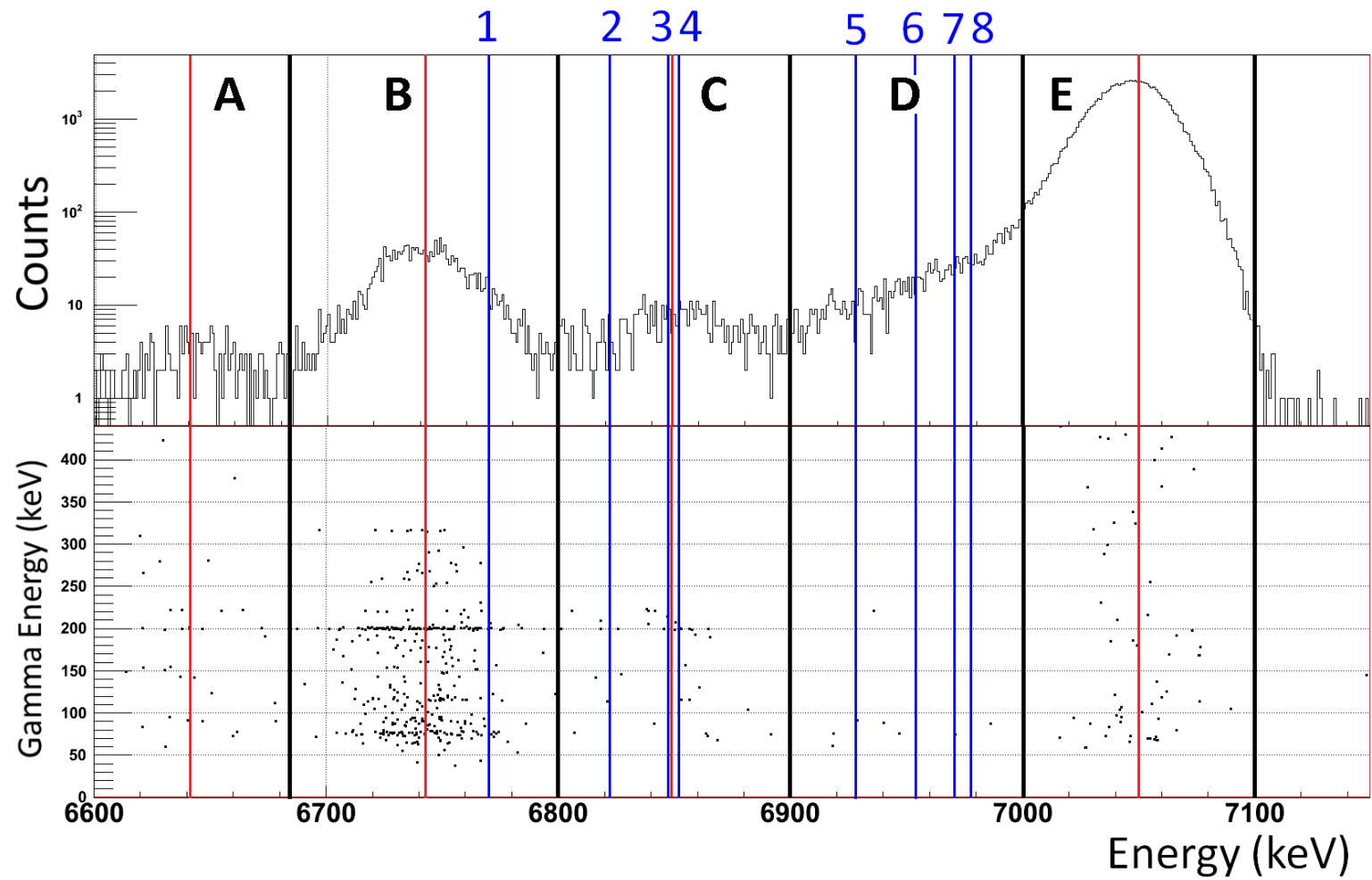


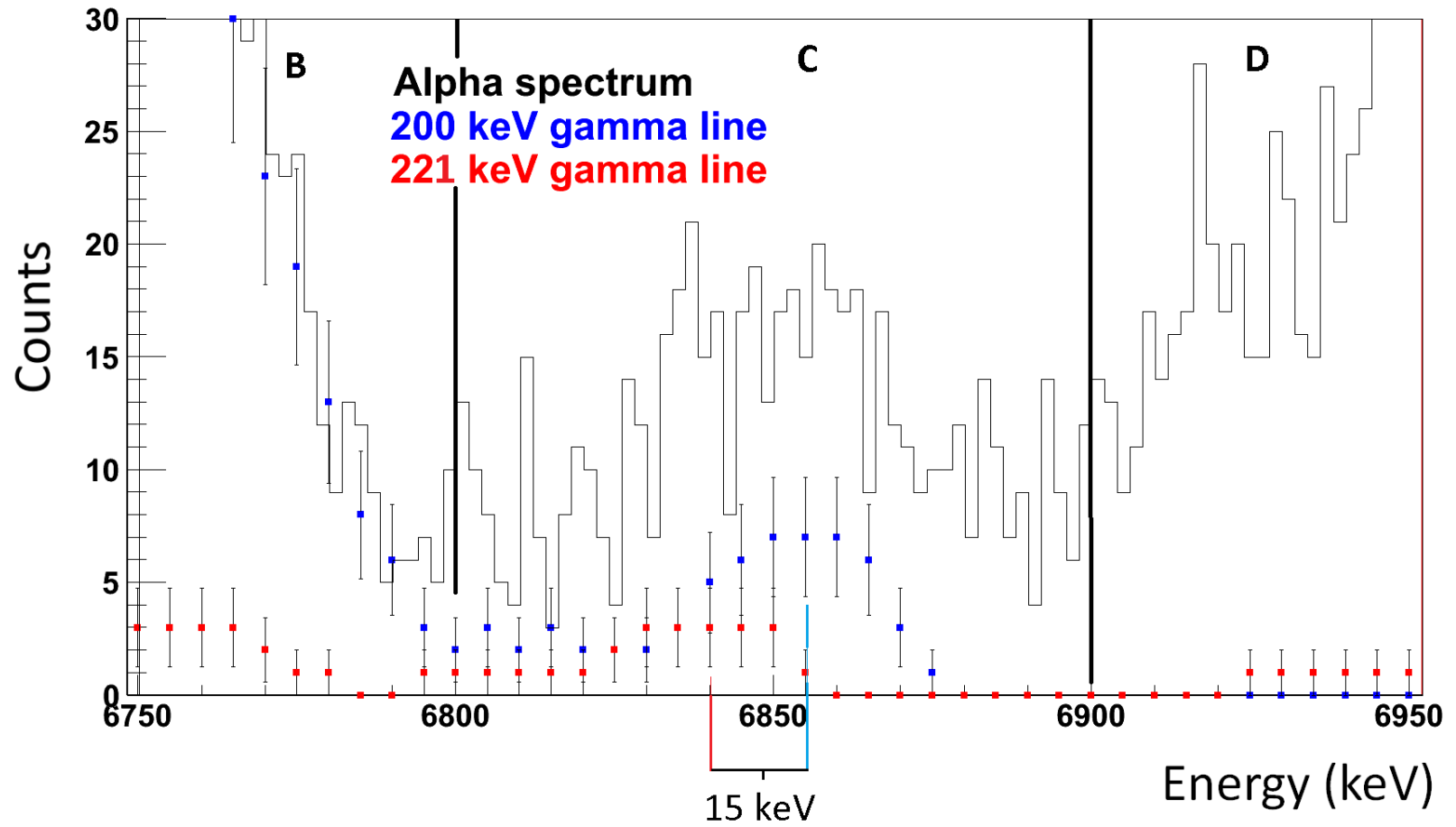






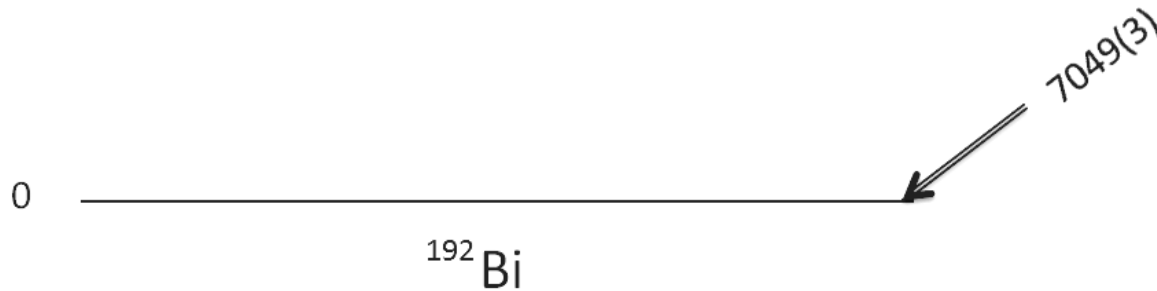






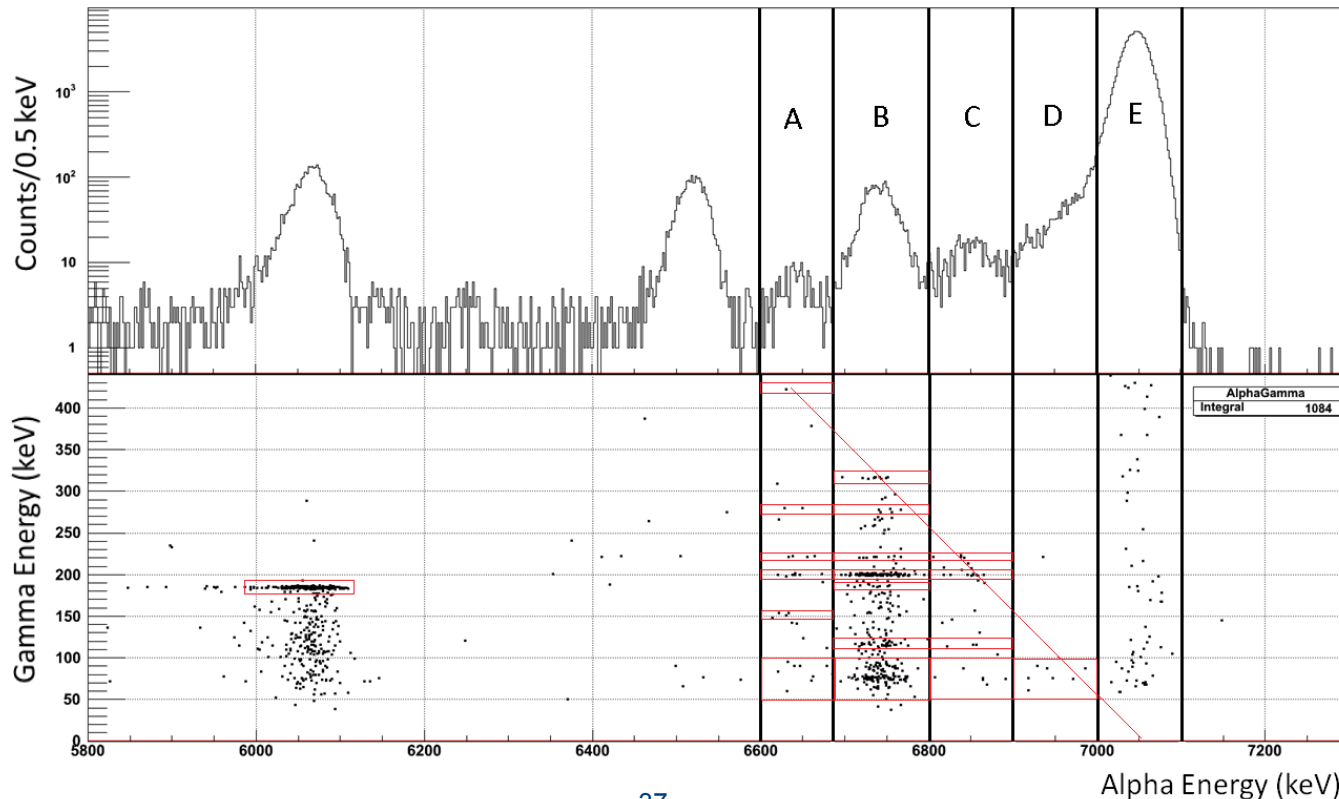
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# Analysis : $\alpha$ -decay spectroscopy

- Fine structure of  $^{196}\text{At}$
- Predominantly gs of  $^{196}\text{At}$  prod



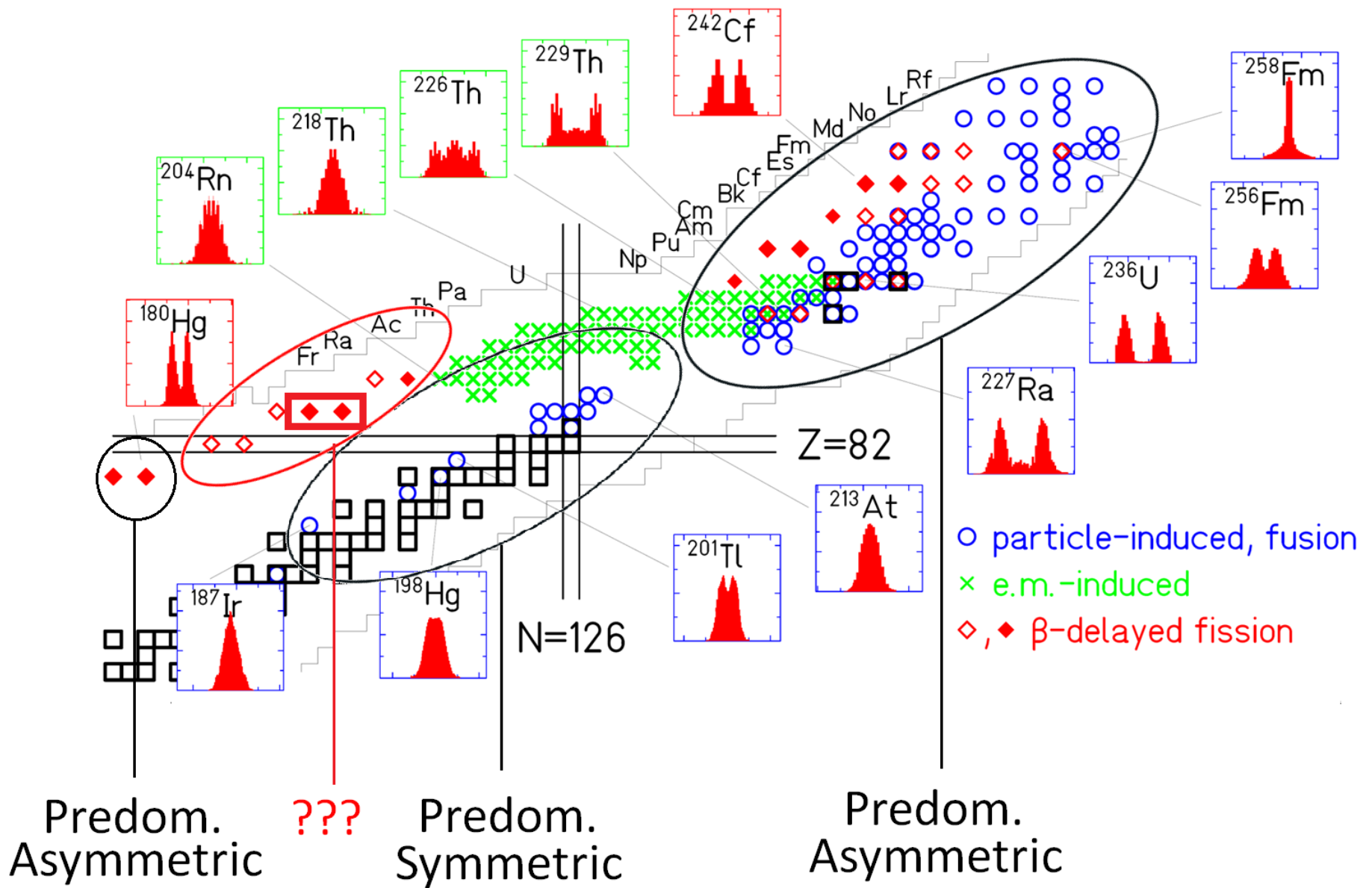
PRELIMINARY !!

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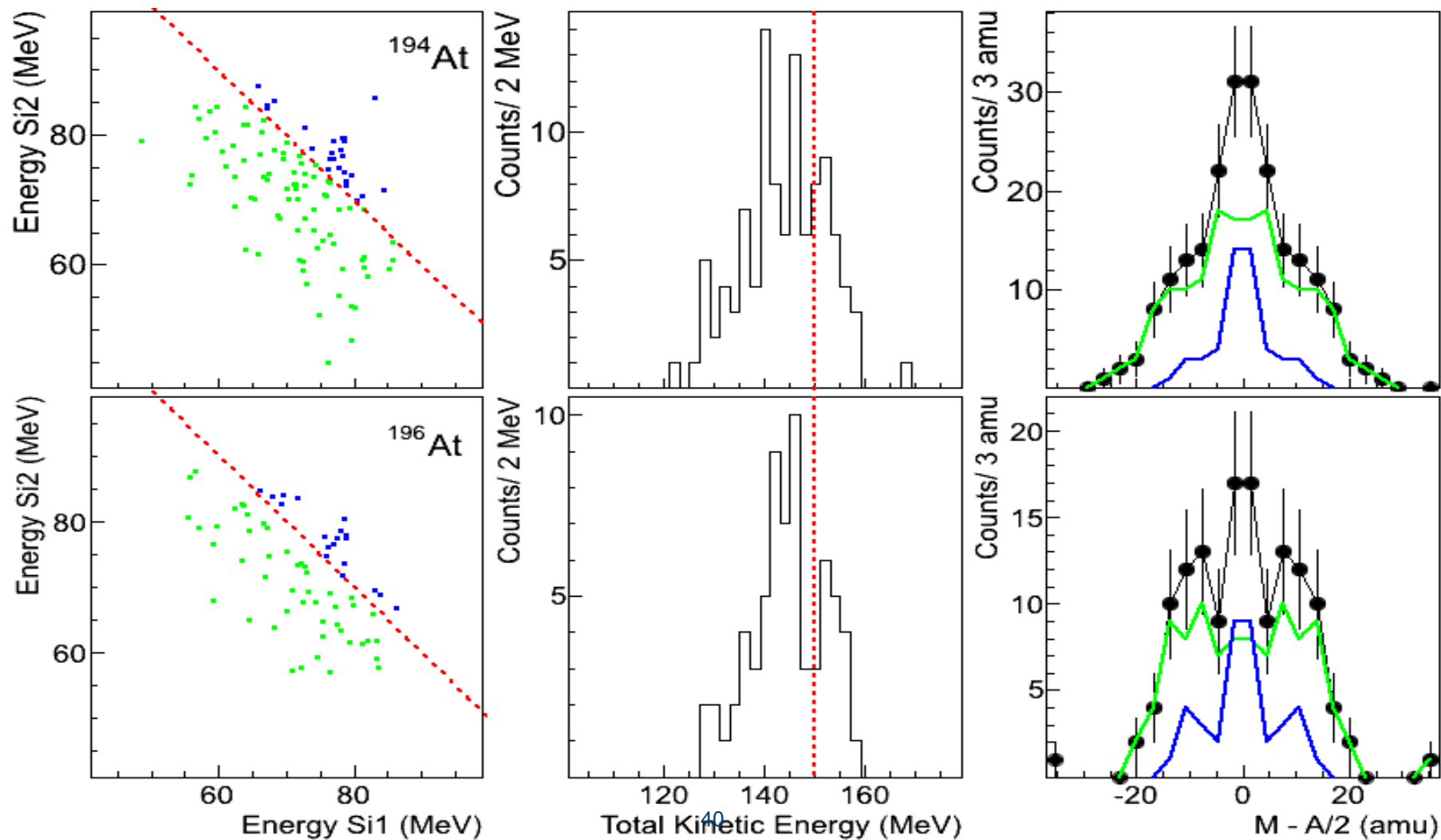


$$b_{\beta}(^{196}\text{At}) = 2.4(1) \%$$

Isotope	T1/2 (s)-(Exp)	T1/2 (s)-(Lit)
196 At	0.373(3)	0.388(14)
196 Po	5.73(11)	5.60(8)
192 Bi	33.2(14)	34.6(9)



# Results for





# Analysis : $\beta$ DF of $^{194,196}\text{At}$

$$P_{\beta\text{DF}} = 9(1) \times 10^{-5}$$

$$T_{1/2,\text{part}}(\beta\text{DF}) = 17(2) \times 10^4 \text{ s}$$

